



## **Proceedings of the 18th International Conference on Engineering Design (ICED11)** **Book of Abstracts**

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18TH INTERNATIONAL CONFERENCE ON  
ENGINEERING DESIGN, 15 - 18 August 2011

*IMPACTING SOCIETY THROUGH  
ENGINEERING DESIGN*



# PROGRAMME & ABSTRACT BOOK

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## THE 18TH INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN

15 - 18 August 2011  
 Technical University of Denmark (DTU)

Organised by  
 Section for Engineering Design and Product Development  
 at the Department of Management Engineering at DTU  
 and the Design Society

### PROGRAMME & ABSTRACT BOOK

Edited by  
 Anja M Maier  
 Krestine Mougaard  
 Thomas J Howard  
 Tim C McAloone

Graphics by  
 Krestine Mougaard

## CONFERENCE PROTECTOR

His Royal Highness Crown Prince Frederik of Denmark is the official protector of the ICED11 conference.



Photo by: Steen Evald

## CONFERENCE SPONSORS

We are proud of the collaborations formed with the conference sponsors listed below, and are very grateful for the contributions they have made to the conference.



## PREFACE BY THE CONFERENCE CHAIR

With these, the proceedings of the eighteenth International Conference on Engineering Design, ICED11, it can safely be stated that engineering design research is firmly established as a strong research discipline. In its 30 year history this is the first time that an ICED conference has returned to the same city, "Wonderful Copenhagen". In the Danish official "Year of Design" the city is the perfect conference location, hosting the highest quality design, ranging from industrial design, through stunning architecture, to a dynamic engineering design industry, which has extensively backed the ICED11 conference.

As design researchers, design practice is our research object and industry companies are our research laboratories. Based on our observations, discussions and participation in design activities, we gather knowledge and insights and crystallise these into both academic models and practical methods. Our customers are students, in training as the product developers and innovators of the future, and industrialists, engaging with us to get insight into tools and methods, which fit to their practices and empower them to meet the challenges of global competition.

The theme we have chosen for ICED11 is *Impacting Society through Engineering Design*. Design has a central role in bringing engineering and technology to practical use. Each of the 416 papers in these proceedings provides its own contribution to the ICED11 theme. We're delighted to see the variety and the quality of contributions that our colleagues from the design research community have contributed to ICED11.

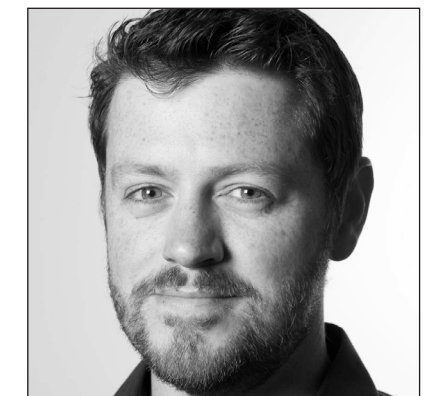
We have taken great care to create a conference showing leading edge research into engineering design and product development practice and to provide a lively backdrop for knowledge exchange and research discussion.

Our goals with ICED11 have been to place particular emphasis on industry participation, provocative and relevant keynote speeches, maximum time for debate and discussion, and space to go in to depth, via the SIG workshops. And all this with a Danish flavour, which we hope you find welcoming, fun and "hyggelig"!

Welcome to ICED11!



Tim C McAloone  
Conference Chair



Thomas J Howard  
Assistant Conference Chair



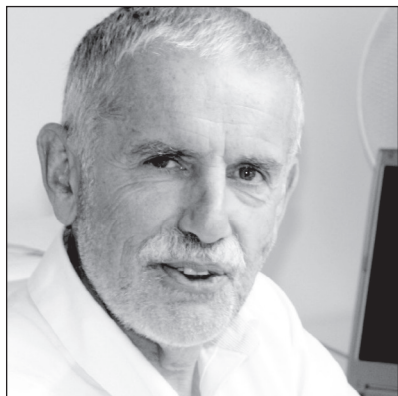
## WELCOME TO THE ICED11 PROCEEDINGS!

A large team of individuals working together are responsible for the selection of the 416 papers being presented here at ICED11, the establishment of the themes, sessions and the creation of the podium and discussion activities. This team consists of the programme chairs, the theme chairs and their assistants, and last but by no means least the reviewers. In particular, the written comments of the reviewers have been critical to the programme team in making their final choices and grouping papers into the conference themes.

The papers have been collated into a multiple range of formats: a book of abstracts, a memory stick of full proceedings and ten volumes of proceedings, available via a print-on-demand supplier. These have been numbered against both Design Society and ISSN referencing. This will enable more extensive access, referencing and citation in the future.

For ICED11 there is no difference in prestige between the papers in podium and discussion sessions. All have passed the ICED quality threshold and papers in the discussion sessions have been selected and grouped to stimulate fundamental and exciting debate. To facilitate this we have put in place a new 5 x 5 format – 5 slides in 5 minutes. We are also introducing a number of techniques to encourage audience participation and for the first time we are trialling live minute taking – so as to provide a record of the debates. Further to this, recorded interviews with all the theme chairs will be undertaken on the final day of the conference so that there is also a persistent summary of each theme, following the conference. The records from the discussion sessions will be made available at the conference and also uploaded to the DS website alongside the interviews with the theme chairs.

We hope that you enjoy the programme and participate fully in what is arguably the Premier engineering design research conference in the world. We also hope that you find time to enjoy Copenhagen, catch up with old friends and make some new ones.



Steve J Culley  
Programme Chair



Ben J Hicks  
Assistant Programme Chair

## PREFACE BY THE DESIGN SOCIETY PRESIDENT

The International Conference on Engineering Design (ICED) is the flagship conference of the Design Society, a Society created in 2001, on the foundations laid by Workshop Design-Konstruktion (WDK), to promote the development of the understanding of all aspects of design. The ICED conferences were inaugurated in 1981 in Rome, and with one extra conference have been held every two years since then, in fifteen countries of the world. Thirteen conferences were held under the auspices of WDK, and this is the fifth organised by the Design Society. It is also the first time that ICED has returned to a city in which the conference has been held before – Copenhagen was the second host city in 1983, and this revisit is most appropriate in view of the leading role that the city and its technical university have played in design research and practice over many years.

The 2011 Conference continues the format established in 2009, with a programme made up of plenary sessions, podium presentations, discussion sessions with focused debate and workshops led by the Design Society's Special Interest Groups. We hope that this varied programme, combined with extensive opportunities for networking, will provide an exciting possibility for researchers and practitioners to learn about the latest developments in engineering design.

Organising an international conference takes an enormous amount of work, and I would like to express the thanks of the Society to the great team that has worked over many months to ensure the success of the Conference. Especially I would like to thank Tim McAlone, Tom Howard and colleagues at the Technical University of Denmark for their great work in the Organising Committee, and Steve Culley, Ben Hicks and the Programme Committee for bringing together such an excellent programme. Of course, their work would be in vain without the fantastic contributions of the authors, reviewers, theme chairs and session chairs, and the thanks of the Society are due to all of them.



Chris A McMahon  
Design Society President

## WE BELIEVE IN DESIGN!

Throughout the summer of 2011 three momentous design events take place on Danish grounds. In addition to the ICED11 conference held in August, Copenhagen will also host the INDEX: Award - the largest monetary design award in the world, in early September. The Copenhagen Design Week will also be held at the same time and will gather together a range of different design disciplines. These events provide a unique opportunity for Danish companies to gain insight and knowledge on the use and applicability of design as an increasingly important aspect of a company's competitive performance on the global market.

Today, Danish companies find themselves in fierce global competition. In a dynamic global market, it is easy for consumers and companies to acquire the goods and services which match their specific needs from multiple suppliers and producers. More and more companies around the world are able to produce the same product or service often at lower costs than is possible in Europe. In this market, maintaining a technological advantage is often not enough to make Danish companies' products and services stand out. Danish products and services have to be attractive to global consumers - the extra quality, functionality, form and feel that justify the extra expense are essential. The key is design.

Denmark has an important and valuable design tradition, where design and innovation are no strangers to Danish companies. It is clear that they are familiar with the benefits of design as more than 90 percent of Danish companies either work with design or apply external design services. What differentiates the companies is how strategically design is used and how well design is integrated into the development process.

Research shows that companies who are using design as a central and integrated part of their innovation and business processes have a higher value increment and are more frequently developing innovative products, processes and businesses than companies who are only using design in the more traditional way, such as for styling or finish.

In spite of the potential benefits and our design tradition, one third of Danish companies are still only using design in the traditional way and have not yet embarked on the path of integrating design into their innovation and business processes.

At the same time - we have been challenged. The so-called "Danish Design" is a widespread and well known brand around the world, especially when it comes to high-end products. However, ambitious companies and designers around the world are gaining ground and it takes continuous effort to maintain the Danish brand and position. Companies and industries around the globe have ignited their innovation and design endeavours in the quest for competitive advantage, and the Danish brand runs the risk of becoming outdated.

Danish companies have to be smart in their approach to design. It must be integrated as a strategic, innovative and applicable key feature. The ICED11 conference offers unique opportunities for Danish companies to gain insight to the forefront of the design and design engineering field, which is a crucial step towards making Denmark a frontrunner in excellent design use and application - for now as well as in the future.



Lars B. Goldschmidt  
Deputy Director General of DI



Confederation of Danish Industry

*Through their sponsorship, DI will be attracting some 50+ industry delegates to the conference and will be holding an industry workshop on Tuesday afternoon.*

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**Schabacker, Michael** - Otto-von-Guericke University Magdeburg, (DE)  
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**Siadat, Ali** - Arts et Metiers ParisTech, (FR)  
**Sigurjónsson, Jóhannes B.** - Norwegian Inst. of Science & Technology, (NO)  
**Simmons, John** - Heriot-Watt University, (UK)  
**Simpson, Timothy W.** - Penn State University, (US)  
**Snider, Chris** - University of Bath, (UK)  
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**Taura, Toshiharu** - Kobe University, (JP)  
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**Torry-Smith, Jonas Mørkeberg** - Technical University of Denmark, (DK)  
**Troussier, Nadege** - Université de Technologie de Compiegne, (FR)  
**Törlind, Peter** - Luleå University of Technology, (SE)  
**Udiljak, Toma** - University of Zagreb, (HR)  
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**Vukic, Fedja** - University of Zagreb, (HR)  
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On behalf of the entire community we would like to express our gratitude to the work performed by our scientific committee. The reviews of the scientific committee were used by the programme committee to make informed accept/reject decisions for each submission and by the authors to make the appropriate amendments to their papers.

In addition, the reviews also allowed the programme committee to acknowledge the top 5% of papers based on the scores given by the reviewers; look out for the following emblem throughout the abstract book:





## DESIGN PROCESSES

Theme chair: John Clarkson

Assistant chair: David Wynn

Engineering processes are the 'glue' that hold the activities within product development and design together. The papers in this theme describe this glue from a variety of theoretical and practical perspectives. There are discussions on: the development, utility and validity of theories of design. There are studies on lean thinking, early stage design, decision making processes, collaborative design and value engineering. There are thoughtful reflections from disciplines as diverse as mechatronics, aerospace, textiles, sanitation and naval architecture. There are descriptions of a wide variety of approaches and tools, targeted at: measuring and improving process performance; managing change in products, services and processes; and modelling complex product and process systems.

There are also papers that usefully cover more than one of these topics. In summary we are presented with a rich mix of ideas, focused around a common desire to improve our understanding, description and management of design processes, and in tune with the latest trends and interests of design researchers and practitioners alike.



## DESIGN THEORY AND RESEARCH METHODOLOGY

Theme chair: Yoram Reich

A design theory is a concise body of knowledge that explains phenomena related to design, including the act of designing and the nature of designs. In engineering, a design theory must contribute to improving designing, and not just improve our understanding of design. Unfortunately, theorising about design is complicated since real design is context dependent, complex, and not repeatable. We could only observe and study one instance of each (real) design project. This makes testing and validating theories hard, and consequently, the methods we exercise to develop and test theories – referred to as research methodology – must be carefully selected to help us achieve the goal of design theories. Given the importance of design theories, the theme – design theory and research methodology – is a foundation for design research and practice.

ICED11 features contributions on design theories including some new proposals, and contribution on research methodology for appraising design research and for studying designers. The contributions are presented in podium and panel sessions that will stir discussions and lead to progress. In addition, ICED11 features a meeting of the design theory SIG of the Design Society that will familiarise those interested in the topic with the SIG activities and progress.



## DESIGN ORGANISATION AND MANAGEMENT

Theme chair: Marco Cantemessa

Previous ICED conferences have always covered the relationship between design and management. However, with ICED11, the connection between the two appears to become significantly closer and quite multifaceted. In particular the ICED11 papers adopt what we might call a "bottom up" perspective - whose objective is to improve the way design processes are executed. Thus the ICED Conference will showcase research papers on the management of design processes, especially within complex settings, with team members that are dispersed from geographical, organizational and disciplinary points of view. Under this perspective, researchers will present methods and metrics for improving the management of the NPD process, including a number of papers that focus on risk management.

However, ICED11 will also include a number of papers that deal with business models, stimulation of innovation, deployment of corporate strategy in the NPD process, and the appropriate handling of user input in order to increase the value of product and service offerings. In contrast to the earlier papers the latter ones view the relationship between design and management in a quite innovative way, from what can probably be termed a "top down" perspective, in which the design process becomes an enabler for high-level decisions that firms take at a strategic level.



## PRODUCT AND SYSTEMS DESIGN

Theme chair: Udo Lindemann

The theme "product and systems design" addresses subtopics like modeling and structuring of products and systems, new ways of generating and optimising systems, integration of further domains (e.g. services), different kinds of applications and complex systems in general. Dealing with variants to meet market demands on one side and economic aspects on the other side is a well-known struggle. To help with this struggle new ideas and methods about product families, platform design and modularisation are presented. How to create a mechatronic system, evaluate its behavior and optimise the system are key questions from a technical point of view and all of them are dealing with interdisciplinary issues. Methods and modelling are discussed in the range of a holistic approach. Interestingly although still a young field of research, a number of papers are devoted to Product Service Systems.

A number of technical applications demonstrate the broad range of use of methods and models and interestingly include, for example, electrical connectors or linear guides, also there are a lot of papers about medical devices and related applications. Automated synthesis is covered by a number of papers which have the aim of helping to generate optimal systems. Finally, there are complex systems such as products and processes that have to be modelled, analysed and managed in an adequate way.



## DESIGN METHODS AND TOOLS

Theme chair: Andy Dong

A "weak signal" is a written sign of a coming change, and is a strategic research method applied by firms, non-profit think tanks, and academics to provide foresight. Thus, rather than looking back at existing design methods and tools summarising what we have developed, perhaps we should look for a "weak signal" to forecast trends we might want to pay attention to. If we were to look at macro trends and link them to issues identified in the body of papers in the theme Design Methods and Tools, what could we identify as a "weak signal" of a sign of new design methods and tools to come? One weak signal is about networks, which appears explicitly in the paper by Jupp, but is also indirectly referred to in papers which employ a Design Structure Matrix (DSM), such as the paper by Schmidt III et al., since any matrix can be re-represented as a network and vice-versa, and, more generally, all papers dealing with large-scale complexity such as the paper by Kissel et al., wherein complex networks is a relatively new field that aims to understand real-world networks such as the Internet or social networks on Facebook. Brain networks, social networks, transportation networks, innovation networks, financial networks - all of these artificial and natural system are being modelled and analysed as a network. We will probably see more design methods and tools based on network analysis in the future, especially to deal with problems such as product architecture and modularity, change propagation and decision-making.



## DESIGN FOR X, DESIGN TO X

Theme chair: Johan Malmquist

Assistant chairs: Lars Almfelt and Andreas Dagman

Design for X Design to X is a broad theme as X can stand for many properties and characteristics of a design - function, performance, cost, quality, manufacturability and many others. As might be expected in 2011, "X" in many of the papers stands for Sustainability. The volume's papers address sustainability on several levels - the society, the company, the team the individual designer. Environmental sustainability is the focus of many of these papers, but you will also find a major group of papers in the volume that consider social sustainability issues, design for human or social factors. New strategic approaches, methods and tool for sustainable design are also introduced. Another major sub-theme in the volume could be described as design for manufacturing in a broad sense. In the volume you will find new methods and tools for manufacturability and quality, for modular design of products and such product interplay with production system, and machine tool design. The potential of mathematical optimisation tools is demonstrated. Further, the volume offers a multitude of case studies and applications, evidencing the potential of DFX methods and tools to improve automotive, construction, healthcare, machine and shipbuilding design.



## DESIGN FOR INFORMATION AND KNOWLEDGE

Theme chair: Wei Chen

Assistant chair: Harrison Kim

Design information and knowledge provides the underpinning support to engineering design processes. The papers in this theme describe this underpinning support from a variety of aspects such as knowledge sharing, search and knowledge discovery, rationale, knowledge transfer and reuse, customer/end-user information, cross-domain knowledge and structuring modules. A wide range of papers cover the practical uses of design information and knowledge systems to address manufacturing, product life cycle, and other industrial issues. Several research themes emerge from these studies. The first is the increasing need for information synthesis to integrate essential information in the early stages of design, such as requirement identification. The second is the need for cross-domain design knowledge representation in large design enterprises as design is fundamentally a complex, group activity with information from many different sources. The third is the potential of applying knowledge discovery and machine learning techniques for identifying and predicting new product design trend. The fourth is the need for developing common taxonomy and ontology for connecting the human-centred design process to the information system on computer. The fifth is the growing interest in methods that facilitate a better understanding of customers and clients' needs early in a design process. In summary the design information and knowledge theme is an emerging area with an excellent prospect for growth in design research.



## HUMAN BEHAVIOUR IN DESIGN

Theme chair: Petra Badke-Schaub

The track Human Behaviour in Design encompasses presentations which focus on the activity of designing in various contexts but also integrate the activity of design research. As with previous ICED conferences a large number of papers focus on designers and the two core issues of collaboration and cognition. The topics of inspiration, creativity and evaluation techniques are also covered and deal with the factors influencing creativity and innovation as well as techniques which are supposed to enhance creativity. Emotion in design is becoming important and here emotion is related to the question of how to steer emotion-related issues in the design process, with focus on the user as well as on the designer. User input and how it is handled is critical in design, thus the topic of user input also receives some considerable attention, with a particular focus on how to integrate user experience into the design process. The other critical entities in design, after the user, are the teams that undertake the work and various aspects of teams such as cultural issues are covered extensively. To set the research agenda it is frequently useful to consider objects and contexts and these are dealt with in this theme through consideration of general views on the product development process and research methods which encompass different methods contributing to the design research process but also dealing with design methodology.



## DESIGN EDUCATION

Theme chair: Bill Ion

Design Education continues to be an important theme within the ICED conference series, particularly as it lays the foundations for the future health and vitality of the industrial and academic design community. The nature of design education cannot be static and needs to incorporate new and enhanced education methods and curricula to reflect current and evolving design practices. For example, in recent years we have seen a significant increase in emphasis on global design practices, which has led to greater emphasis being placed on distributed team working and the management and coordination of activities, knowledge and information within a global context. This is reflected in the design education content of ICED11 where we have a full session devoted to Global Design and other papers addressing the attributes required of a global designer. Likewise, learning approaches are evolving, often facilitated by the increasing power of ICT networks, leading to an increasing emphasis on the use of open learning approaches based on shared use of design educational resources. These aspects are addressed in the papers included within the Design Education theme of ICED11 along with the more traditional, but equally important, topics of how to enhance conceptualisation, assessment, the 'shape' of the designer and the teaching of an increasing range of DFXs.



## MONDAY 15 AUG. 2011

### OPENING CEREMONY

Time: 09:00-09:45 / Location: Main Hall

Chair: Per Boelskifte, Head of the Engineering Design and Product Development Section

After a musical welcome in the Main Hall in, the conference will be opened with speeches from Lars Pallesen, DTU Rector; Per Langaa Jensen, the Head of the Dept. of Management Engineering and Tim McAloone, the ICED11 Conference Chair. This will provide delegates with information about the context in which the ICED11 conference is held. There will also be presented some vital information regarding the week's programme, activities and logistics.

Immediately following the opening ceremony, the Design Society's President, Chris McMahon, will deliver a keynote speech, where he will address the diversity of design research and the opportunities that lie in embracing this diversity.

### WELCOME DRINKS

Time: 17:45-19:30 / Location: Conference venue garden area (subject to weather)

We invite you to toast good health and to sample a Danish hotdog! Some traditional Danish games will be laid out on the Lawn, which we invite you to try your hand at!

### ALUMNI MEETING OF SUMMER SCHOOL ON ENGINEERING DESIGN RESEARCH (SSEDR)

Time: 20:00 / Location: To be confirmed

The SSEDR alumni has quite a following now and has established a tradition of arranging social get-togethers during many of the Design Society's conferences. This year's meeting will take place in Copenhagen city centre; the exact place is to be confirmed.

Further details: Kilian Gericke - Kilian.Gericke@uni.lu

## TUESDAY 16 AUG. 2011

### CITY HALL RECEPTION

Time: 18:30-20:00 / Location: Copenhagen City Hall

Dress: Informal

All conference participants have received an invitation: those who have accepted this invitation will find tickets in their conference pack. Please note that this reception will start punctually at 18:30.

The reception is hosted by the Mayor and the City Council of Copenhagen and will take place at the City Hall. The reception provides a unique possibility to experience the architecture of the City Hall, which is built in the Nordic *National Romantic* style. City Hall Pancakes, wine and soft drinks will be served.

WEDNESDAY 17 AUG. 2011

GALA DINNER

Time: 18:30-23:00 / Location: Nyhavn and Langelinie Pavillonen  
Dress: Informal – a light coat may be useful

The evening starts with a boat trip along the canals – embarking at Nyhavn/Havnegade.

Located on the waterfront with unrivalled views of The Little Mermaid, the restaurant contains some of the finest examples of 1950s Danish design, including Poul Henningsen’s world-famous cone lamps, of which the restaurant is the proud owner of the first eight ever produced. With its superb cuisine, the evening is bound to be a great experience!

See p141 for futher details.

THURSDAY 18 AUG. 2011

CLOSING RECEPTION

Time: 17:00-18:30 / Location: Conference venue garden area (subject to weather)

A chance to say goodbye and tie up loose ends over a few final drinks and snacks, while meeting the hosts of the ICED13 conference.

FRIDAY 19 AUG. 2011

TECHNICAL VISITS

We have arranged two exciting technical visits, combining tours of a selection of Danish product development companies with some local culture and sightseeing. Both delegates and partners/families are welcome. Separate payment must be made for the technical visits, at the conference registration desk. We have limited places, so first-come-first-served!

For further information about our Technical Visits: See p174.

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07:30 - 09:00	Check-In Main Desk in Reception									
09:00 - 09:45	Opening Ceremony Main Hall									
09:45 - 10:15	<b>Design Society Keynote: Embracing the Diversity</b> Chris McMahon, Univeristy of Bath Main Hall									
10:15 - 10:45	Break									
	D Discussion Sessions			P Podium Sessions				W Workshop Sessions		
10:45 - 11:50	Knowledge Sharing Room: Discussion Room 1 Theme: Design Information and Knowledge	p22	Design Innovation Room: Discussion Room 2 Theme: Design Education	p24	Models and Representations of Product and Process Room: Oticon Theme: Design Methods and Tools	p26	Organising Collaborative Design Processes I Room: Podium Room s01 Theme: Design Organisation & Management	p28	Managing Complex Systems Room: Podium Room s09 Theme: Product and Systems Design	p29
							Engineering Economics and Management Room: Podium Room s02-03 Theme: Design Methods and Tools	p30	Change Management Room: Podium Room s10-11 Theme: Design Processes	p31
12:00 - 12:30	<b>Sustainability Keynote: Fossil Dot Com</b> Charles Nielsen, DONG Energy Main Hall									
12:30 - 13:00	<b>Futurology Keynote: When Machines Design Machines!</b> Peter Cochrane, Cochrane Associates Main Hall									
13:00 - 14:15	Lunch									
14:15 - 15:45	Methods for Appraising Design Research Room: Discussion Room 1 Theme: Theory and Research Methodology	p34	Product Families Room: Discussion Room 2 Theme: Product and Systems Design	p36	Digital Modelling and Behavioural Simulation Room: Oticon Theme: Design Methods and Tools	p38	Design Information and Product Life Cycle Room: Podium Room s01 Theme: Design Information and Knowledge	p40	Collaboration Room: Podium Room s09 Theme: Human Behaviour in Design	p41
							Organising Collaborative Design Processes II Room: Podium Room s02-03 Theme: Design Processes	p42	Design for Human Factors Room: Main Hall Theme: Design for X, Design to X	p43
15:45 - 16:15	Break									
16:15 - 17:45	Product Service Systems Room: Discussion Room 1 Theme: Product and Systems Design	p44	Design and Business Models Room: Discussion Room 2 Theme: Design Organisation & Management	p46	Early Stage Design Room: Oticon Theme: Design Processes	p48	User Centered Design Room: Podium Room s01 Theme: Design Methods and Tools	p50	Cognition Room: Podium Room s09 Theme: Human Behaviour in Design	p51
							Cross-Domain Knowledge Room: Podium Room s02-03 Theme: Design Information and Knowledge	p52	Functional Reasoning I Room: Main Hall Theme: Theory and Research Methodology	p53
17:45 - 19:30	Welcome Drinks									

Design Research: Embracing the Diversity



Chris McMahon  
BSc, CEng, FIMechE  
Professor of Engineering Design  
Design Society President

Abstract

Design is a topic that has been studied from many disciplinary perspectives, each bringing particular methodological traditions to bear and yielding many different insights into the subject, but the diversity has meant that it has been difficult to achieve a coherent view on research in the domain. This presentation will explore the nature of this diversity and will propose ways in which the research community may work together to develop a consolidated understanding of the design research space. After first exploring the different communities that contribute to design research, and reflecting on a range of topics that have been studied, a number of ways will be presented in which research in the domain might be characterised, building especially on experiences with ICED conferences in recent years. In particular, design research will be differentiated according to the time scales being studied, the number of participants, the complexity and degree of originality of the design context, the research approach and the degree of abstraction employed. Suggestions will then be made for how the research community may collaborate in the future to identify where there are commonalities and differences in results and approaches.

Biography

Chris is Professor of Engineering Design in the Department of Mechanical Engineering at the University of Bath, which he joined in 2002 from the University of Bristol. In his early career as an engineer he worked in the railway industry and with a consulting engineering company specialising in IC engines. He teaches and researches in engineering design and computer-aided design. He is interested in many aspects of design and computing, in particular how computer aids can assist design in the organisation and management of the information used in design.

Chris is Director of the University of Bath’s Innovative Design and Manufacturing Research Centre, and was Principal Investigator of the EPSRC Grand Challenge project in through-life information and knowledge management for product-service systems. Chris’s other research interests are predominantly concerned with the application of computers to all aspects of engineering design.

Chris is active in design education, and has been involved in the organisation of the Engineering and Product Design Education (EPDE) conferences over a number of years. Chris is also Fellow of the Institution of Mechanical Engineers, and Co-chair of IFIP WG5.1, responsible for organisation of the Product Lifecycle Management (PLM) series of conferences.





THE DIGITAL DIVIDE: INVESTIGATING THE PERSONAL INFORMATION MANAGEMENT PRACTICES OF ENGINEERS

**McAlpine, Hamish Charles; Hicks, Ben; Tiryakioglu, Can**

*University of Bath, United Kingdom*

Whilst there exists a significant amount of work exploring the Personal Information Management (PIM) practices of various general groups of people (such as ‘knowledge workers’), or specific PIM tools (such as email, or task management tools) there has been considerably less research focussed on the wider PIM practice of engineers. Furthermore, the revolution in working practices witnessed over the last decade means that previous studies may fail to give an accurate picture of today’s practice.

This research therefore presents a detailed investigation into the PIM practice of 27 engineers working in a range of organisations and across various stages of the product lifecycle is presented. Through semi-structured interviews and a detailed mapping exercise of the engineers’ PIM tools and sources, their ‘information world’ is characterised. The research also sheds light on the relationships between informal PIM tools and more formal document types generated as part of the design process. Users’ satisfaction with their current PIM practice is also revealed, together with the seven most commonly cited issues.

INTERFACE QUALIFICATION BETWEEN THE RESEARCH CENTRAL TEAM AND DESIGN OFFICES IN ORDER TO EVALUATE THE KNOWLEDGE SHARING

**Fraslin, Marie; Blanco, Eric**

*INPG, France*

This article presents a case study which was led in an international company dealing with hydraulic power plant machine design. It exposes a diagnosis of the interface set up between the Research central team (R) and Development local team (D). The diagnosis shows how the information and knowledge are shared among R&D communities. It shows that the explicit knowledge formalized by the Research central team, is known and applied by the local development team, thanks to two types of networking; (1) The networking with experts in charge of communicating and explaining technical instructions applied on project, (2) and the networking between local colleagues. These practices reveal local logic that are not aligned with the company globalisation objectives. Hence we propose an experimentation to complement the current interface.

PERCEPTIONS OF AND CHALLENGES WITH KNOWLEDGE SHARING - ENTERPRISE COLLABORATION IN A VIRTUAL AERONAUTICAL ENTERPRISE

**Johansson, Pär; Johansson, Christian**

*Luleå University of Technology, Sweden*

The purpose of this paper is to investigate how knowledge is managed and shared within product development in an enterprise collaboration context in the aerospace manufacturing industry.

This paper is based on a qualitative survey that was sent to seven companies in the European aerospace manufacturing industry, focusing on how they perceive knowledge sharing, and on common problems and challenges with knowledge sharing.

Lack of trust and fear of losing competitive advantage is identified as a problem area. Further, information and communication technology is seen as an important enabler. In this area it is found that it is important to develop strategies for knowledge sharing in collaboration with business developers, engineering, and IT architects from various organizations in the extended enterprise.

CASE STUDIES TO EXPLORE INDEXING ISSUES IN PRODUCT DESIGN TRACEABILITY FRAMEWORK

**Pavkovic, Neven (1); Bojcetic, Nenad (1); Franic, Leonard (2); Marjanovic, Dorian (1)**

*1: University of Zagreb, Croatia, Republic of; 2: Koncar MES, Zagreb, Croatia*

Little is currently understood about the requirements for engineering information traceability in product development environment, and there are few methods by which effective traceability can be ensured. First part of paper presents two case studies: an analysis of current traceability practice in automotive industry supplier, and an experiment in implementation of taxonomy based software tool for knowledge indexing in medium sized company. Based on findings from case studies, the further research seeks the answers how the ontology based approach to defining the context and associated set of indices could lead towards generation of navigable semantic network that will be able to fulfil complex traceability requirements in customizable environment. Proposed approach suggests the definition of the context for tracing by "extracting" the subsets of ontology. Elements of ontology subset are associated with information objects (design documentation) belonging to design episode which is to be traced. Tracing procedure is focused (but not exclusively) on events that are the part of the process of information object management in PLM system.

IDENTIFICATION, TRANSLATION AND REALISATION OF REQUIREMENTS FOR A KNOWLEDGE MANAGEMENT SYSTEM IN AN ENGINEERING DESIGN CONSULTANCY

**Thomson, Avril Isabel**

*University of Strathclyde, United Kingdom*

This paper provides an overview of the development of a Knowledge Management system for an engineering design consultancy. It sets out a methodology from the initial importance of identifying requirements based on the particular organizational context through to training and roll out. This paper explores the issues associated with the early stages of knowledge management intervention, exploring the methodology utilized from the study of existing practice through to software development. Techniques employed as part of this methodology include the study of existing practice, user requirements mapping, and business and software specification development. The translation of these requirements and specifications into system features are illustrated by focusing on three key themes identified during the project: a reluctance to contact other regional offices, the time burden of finding existing design knowledge and capturing new design knowledge, and robust validation procedures. It is anticipated the techniques utilized and insights gained will be directly applicable to other organizations, particularly those in the engineering design sector, seeking to implement a knowledge management system.

KNOWLEDGE SHARING APPROACHES IN METHOD DEVELOPMENT

**Thor, Peter; Wenngren, Johan; Ericson, Åsa**

*Luleå University of Technology, Sweden*

Product-Service Systems (PSS) or, life-cycle offerings, is a challenge for knowledge sharing within manufacturing industry due to an integration of intangible (tacit) and tangible (explicit) domains. One consequence is that the engineers’ have to make sense of abstract customer information in early development. For this, they need computer support. Method developers are employees that are responsible for in-house development of such support. There are similarities in their contemporary work practices and some aspects of the development of life-cycle offerings. The intent in this paper is to draw from the method developers’ experiences in managing acquisition of user information for the purpose to contribute to knowledge sharing in early development. We have found that the problem-setting approach applied by the method developers could help the identification, analysis and application of user needs, thus also could be applied to identify metrics/characteristics for intangibles.

# Design Innovation

Theme: Design Education  
Chair: Ion, William

## IMPLEMENTING DESIGN CRITIQUE FOR TEACHING SUSTAINABLE CONCEPT GENERATION

**Bernstein, William Zev; Ramanujan, Devarajan; Cox, Monica F; Zhao, Fu; Sutherland, John W; Ramani, Karthik**

*Purdue University, United States of America*

Product design is one of the most important activities that can influence sustainability. Therefore, it is critical to educate students about these methodologies as they are the next generation of engineers. This paper details a study conducted among engineering graduate students for teaching sustainability through design critique. The students were part of a graduate level design course and were required to conceptualize designs of novel products. Upon completion of their designs, questionnaires which assessed their familiarity with sustainable design and its relation to product design were handed out. A team of design experts reviewed the final design concepts along with these questionnaires and offered a detailed design critique focused on redesign with regards to sustainability. The students then revised their design based on the feedback. A post-evaluation questionnaire and the modified design concepts were then collected to assess the success of the design critiques. Although student projects are limited in scope, and simplify real world problems, the learning through this project will enable them to design products that consider environmental sustainability.

## FLUENCY AND FLEXIBILITY OF CONCEPTS ARISING FROM PERSONALISED IDEATION TECHNIQUES

**Field, Bruce William**

*Monash University, Australia*

When presented with a novel problem, a novice designer faces the daunting task of formulating suitable concepts to develop into a solution. Some novices, with a creative flair, can easily conceive several potential solutions. Various design methods have been published to help engineers generate ideas. Studies show that designers who generate many possible solutions to a problem are more likely to identify one of high quality. At Monash University, 244 undergraduate engineering design students were individually presented with a real design problem in which a split pin fastener was deemed unreliable, and were asked to propose plausible options. Only 44 students chose to apply a systematic ideation technique. Those who used Morphology generated a slightly below-average number of options, of limited variety. Other students who applied a Classification technique generated a greater number of options, with more variety. In a parallel investigation, it was confirmed that those students with better spatial skills tended to generate options with more variety and perform better in the design course in which they were enrolled, whether or not they used systematic design methods.



## A ‘THEATRIC’ APPROACH TO THE TEACHING OF DESIGN

**Matthews, Jason; Medland, Anthony**

*University of Bath, United Kingdom*

Design teaching is complicated due to its context specific nature. The teaching of it as an academic subject focuses on the core technologies of embodiment, detailing and manufacture. In order to put these into context issues that establish the background and also the success of the design should really need to be considered. These are expressed here in theatrical terms as providing the prologue and epilogue around the main ‘play’. The prologue establishes the background and sets the design into the specific nature of the problem being handled through an understanding of the broader issues of the originality of the problem, the frequency with which it has been addressed as well as the current exploitation and commercial application. The epilogue is often ignored during teaching as the solution is expected to follow the core processes and lead directly to a solution. In ‘real’ design there is often the case that the chosen solution may not meet all of the requirements or the original brief may have failed to cover items that subsequently turned out to be important. The inclusion of these additional aspects of design allows the context and core issues of design to be better understood.



## DEVELOPING A DRAWING CULTURE: NEW DIRECTIONS IN ENGINEERING EDUCATION

**de Vere, Ian; Kapoor, Ajay; Melles, Gavin**

*Swinburne University of Technology, Australia*

Sketching is integral to the design process, as it allows reflection in action, enables ambiguity and abstraction, encourages the unexpected, externalises mental imagery, and provokes creativity though analogical reasoning and reinterpretation. The articulation of the concept facilitates a discussion not only with peers and clients, but more importantly with oneself in a reflective practicum. In the context of engineering practice, sketching serves multiple social and cognitive functions throughout all stages of the product design and development process. Fundamentally sketching is the ‘first language’ of all designers and it is apparent that the design process can be limited by one’s capacity to use drawing for cognitive exploration. It is therefore essential that development of drawing skills is integrated throughout engineering education. This paper discusses curriculum initiatives aimed at developing a drawing culture amongst product design engineering students. ‘SketchFest’ is a sketching and ideation program that augments existing drawing skills, introduces new techniques and promotes student awareness of the value of sketching in product design and development.

## EXPLOITING HAND SKETCHING IN EDUCATING ‘MECHANICALLY ORIENTED’ ENGINEERING STUDENTS

**Farrugia, Philip; Borg, Jonathan; Camilleri, Kenneth**

*University of Malta, Malta*

In our years of experience in training mechanical engineering students we found a strong tendency that due to the overall knowledge transfer they receive, these future engineers tend to be oriented in mainly thinking and presenting details of their design solution. Whilst clearly design solutions need to be eventually described in detail for their successful realization, our experience also shows that many times, good detailed design solutions do not make up for poor solution concepts generated. In this paper, we therefore present the overall pedagogic approach adopted at the University of Malta in exploiting sketching both for expressing working principle solutions and also for early form design. In addition, this paper will outline how a prescribed sketching language was developed to enable co-located designers to quickly express and exchange 3D Computer-Aided Design (CAD) models of their solution sketches, all this helping in making 'global design' truly feasible even at the early design stages.

## ASSESSING QUALITY OF IDEAS IN CONCEPTUAL MECHANICAL DESIGN

**Lewis, William P (1); Field, Bruce W (2); Weir, John G (1)**

*1: The University of Melbourne, Australia; 2: Monash University, Australia*

A recurring theme in engineering design is the need to upgrade the performance of existing systems and products as potential defects overlooked in the original design come to light during operation and maintenance. This paper is concerned with the evaluation of skills exercised by designers when trying to solve “improvement” problems with attention focussed on their creative effort during the conceptual design phase. An investigation has been carried out in which an “improvement” problem selected from industrial practice was presented individually to thirty senior mechanical engineering students. Systematic analysis of their responses required the development of new research tools, firstly for assessing the quality of the design concepts proposed, and secondly for modelling the processes of ideation and argument used by each designer. Results are presented in terms of metrics for fluency of ideation, quality of concept, and branching preference, a new characteristic of designer performance found in this investigation. Further research is being undertaken to confirm the utility of the new research tools and the validity of the results obtained from their use.

## A PROCESS OF CONCEPTUAL ENGINEERING DESIGN FOR NEW PATENTABLE PRODUCTS

**Lloveras, Joaquim**

*Technical University of Catalonia, Spain*

The conceptual design phase is a few-structured phase, and it is especially true for to create a new product that can be patented. In this paper is proposed a procedure to do a conceptual design phase of a new product. A well-structured top-down search of solutions with creativity techniques in successive levels of solutions, with Ecodesign strategies and of writing patent, helps to have new concrete ideas of solution and to prepare the design to the phase of detailed design. Three stages are identified: Conceptual design directed; conceptual design defined, and conceptual design viable. This initial procedure it is basically followed in a new free elective course of UPC called: Creativity, Ecodesign and Patents. This course is especially thought for product design initial phases. Writing a patent of product in this initial conceptual phase of design, helps to clarify and refine easily some solutions and to think alternatives of solution. This redaction prepares the final patent redaction when the detailed design ends.

# Models and Representations of Product and Process

Theme: Design Methods and Tools  
Chair: Andreassen, Mogens Myrup

## COMPUTATIONAL REPRESENTATIONS FOR MULTI STATE DESIGN TASKS AND ENUMERATION OF MECHANICAL DEVICE BEHAVIOUR

**Todeti, Somasekhara Rao; Chakrabarti, Amaresh**

*Indian Institute of Science, Bangalore, India*

The role of a computer emerged from modeling and analyzing concepts (ideas) to generate concepts. Research into methods for supporting conceptual design using automated synthesis had attracted much attention in the past decades. To find out how designers synthesize solution concepts for multi-state mechanical devices, ten experimental studies were conducted. Observations from these empirical studies would be used as the basis to develop knowledge involved in the multi-state design synthesis process. In this paper, we propose a computational representation for expressing the multi-state design task and for enumerating multi-state behaviors of kinematic pairs and mechanisms. This computational representation would be used to formulate computational methods for the synthesis process to develop a system for supporting design synthesis of multiple state mechanical devices by generating a comprehensive variety of solution alternatives.

## ABSTRACT PROTOTYPING IN SOFTWARE ENGINEERING: A REVIEW OF APPROACHES

**Du Bois, Els (1); Horvath, Imre (2)**

*1: Artesis University of Applied Sciences, Belgium; 2: Delft University of Technology, The Netherlands*

Abstract prototyping (AP) is a pre-implementation testing approach in software engineering, based on low-fidelity prototypes. It supports demonstration and evolution of software concepts at an early stage. It allows designers to optimize the operation of the software and allows end users to understand how to work with the system. In this paper we survey various ‘approaches’, i.e. both the way of developing the content of AP and the manner of using them in software engineering. We developed a reasoning model intuitively and defined research questions to structure our review and this paper. Our objective was to get insights in the existing definitions, information contents, construction processes and application opportunities for AP. We have found that AP is simultaneously a challenging scientific and a complex practical issue, which usually raises a large number of sub-issues and questions. In addition we observed that there are multiple interpretations of AP which are disturbing a clear picture. Based on the findings we observed that it is possible to generalize the key constituents of AP and to integrate them into a simplified and application-independent AP methodology.

## USE OF CONSTRAINTS IN THE EARLY STAGES OF DESIGN

**Mullineux, Glen**

*University of Bath, United Kingdom*

At the very early stages of original design work, the aspects of concept, scheming and analysis tend to merge. It is only as the designer’s understanding of the design task increases that these aspects become more substantial and start to separate into distinct activities. The challenge in providing support in the early stages is that the design, and hence its geometry, is necessarily ill-defined. This paper looks at the use of constraint-based techniques as a design aid. Constraints are more clearly identified as they bound what is possible. They allow an initial model of the design to be created from the little that is known. This can be expanded as the design progresses, and, being constraint-based, previously created parts of the model can be refined in the light of subsequent design progress. These ideas are illustrated with an application based on the design of an “erection” system for cartons used for packaging. At the start of the design, all that is known is the form of the carton net. This is modeled to determine the required motion. The constraint model is then expanded to consider the basic folding mechanisms and the requirements for guiding faces

## INTERDISCIPLINARY SYSTEMS MODELING USING THE CONTACT & CHANNEL-MODEL FOR SysML

**Albers, Albert; Christian, Zingel**

*Karlsruher Institute of Technology (KIT), Germany*

Technical products are nowadays complex systems. Many specialized engineers develop highly mechatronic systems. Unfortunately, this still happens under insufficient conditions. Not only capable tools are missing for imaging comprehensive system understanding and knowledge, yet an adequate overall language for product engineers is still not in use.

This paper presents an approach to perform modeling of technical systems in SysML using the Contact & Channel approach (C&C-A). The intention is to combine the strengths of SysML in visual modeling of complex systems with the capabilities of C&C-A in analysis and synthesis of technical systems’ form and function. The aimed result is to provide an easily manageable software-based language for interdisciplinary systems modeling.

This work introduces the first realization step, an integrated software-based modeling of system structures. For this purpose, SysML and C&C-A are initially introduced. Afterwards, the C&C-A metamodel for SysML is elucidated. An application example is used to demonstrate the intuitive employment of this modeling approach. Concluding, an outlook towards future research tasks is given.

## MODELS AND SOFTWARE FOR CORRUGATED BOARD AND BOX DESIGN

**Sohrabpour, Vahid; Hellström, Daniel**

*Lund University, Sweden*

To design and develop boxes which protect, and at the same time utilize fiber material efficiently, models and software for predicting corrugated board and box properties are needed. The purpose of this research is to provide propositions toward improving the use and development of models and software for corrugated board and box design. By using an abductive approach, 18 models and four software for predicting corrugated board and box properties were identified, compared, and categorized depending on the needs of different supply chain actors. Eight of the models use paper properties for predicting board properties while ten models predict corrugated box properties. In order to decrease the gap between theory and practice new insights, in the form of propositions toward improving the use and development of models and software for corrugated box design, are suggested. A holistic perspective for modeling corrugated board and box is proposed and enables practitioners and researchers to identify causes to variation in predictions by considering control and noise factors.

## A METRIC TO REPRESENT THE EVOLUTION OF CAD/ANALYSIS MODELS IN COLLABORATIVE DESIGN.

**Drémont, Nicolas (1); Gaignic, Pascal (1); Troussier, Nadège (1); Whitfield, Robert Ian (2); Duffy, Alex (2)**

*1: UTC, France; 2: University of Strathclyde, UK*

Design process is dynamic and uses an important number of models during its progress. CAD (Computer Aided Design) models and CAE (Computer Aided Engineering) are used during design and an important number of interactions must be mastered between the different models of the designed system to be robust and in accordance with initially defined specifications. An important number of works exist on the link between digital mockup and analysis models. However design/analysis integration must take into consideration the models multiplicity (digital mockup and simulation) due to model evolution in time, but also to system engineering. To manage the modifications on the system, and the V cycle, the dependence links between the different models must be known and the nature of the modification must be characterized to estimate the impact of the modification among dependent models. We propose to describe the nature of a modification and by consequence to help to know the necessity to spread in other models and the way to qualify modified information. For this, a metric is proposed allowing to qualify/evaluate data/information, based on the maturity and validity of information and models.



# Organising Collaborative Design Processes I

Theme: Design Organisation and Management  
Chair: Larsson, Tobias C.

## EXPLORING COLLABORATION IN A NETWORKED INNOVATION PROJECT IN INDUSTRY

**Bergema, Katinka (1); Kleinsmann, Maaike (1); Valkenburg, Rianne (2); Bont. de, Cees (1)**

1: Delft University of Technology, Netherlands, The; 2: The Hague University of Applied Sciences

The growing complexity of the increasing need to design product service systems forced companies to collaborate in innovation networks. Networked innovation requires different stakeholders to design together. Stakeholders do not only come from different disciplines, but they also come from different organizations and companies. The collaboration in these networked innovation projects therefore reaches another level. This introduces new issues to the literature on collaboration in mono- and multidisciplinary teams. This paper is about an explorative study in which we investigated in what way networked innovation differs from ‘normal’ innovation projects within a single company. We found similar and additional factors that influenced collaboration. However, the effect and manifestation of the factors found differed from a multidisciplinary team within one company. The findings will form a proper base to guide our future research.

## ON THE STABILITY OF COORDINATION PATTERNS IN MULTIDISCIPLINARY DESIGN PROJECTS

**Castro, Joao (1); Steinert, Martin (2); Seering, Warren (1)**

1: MIT; 2: Stanford

Participants in product design and development projects need to interact to coordinate the impacts and dependencies of their work on the product. Based on data from NASA rocket design projects we analyze and compare a series of product development projects within the same organization where objectives and team composition differ. We focus on the connections that are made between team members and the nature of the project and relate the two. Findings reveal that similar design problems exhibit similar dependency structures and allow for organizational learning opportunities.

## A HOLISTIC PROCEDURE FOR PROCESS INTEGRATION IN DESIGN COOPERATION

**Beyer, Christiane (1); Grote, Karl-Heinrich (2); Kubisch, Christian (3); Tegel, Oliver (3)**

1: California State University, Long Beach, United States of America; 2: Otto-von-Guericke University, Magdeburg, Germany; 3: Dr. Ing. h.c. F. Porsche AG, Germany

In preparatory stages of an upcoming cross-company cooperation an integration project has the task to establish best possible connections between relevant organizational units. Therefore the integration of company sub-divisions willing to cooperate has to be accomplished under the conditions of insufficiently pre-evaluated management specifications, limited project time and resources as well as strongly diverging requirements of affected operating departments. Existing approaches of cooperation and process management support integration projects by delivering methodological proceedings and tools, but paying not enough attention to the explicit search for operative processes and their integration under specific project restrictions. Within this article on the one hand the need for strengthening the paradigm of process orientation in cooperation projects is pointed out, and on the other hand an additional, practical instrument for process integration is offered. The authors introduce a holistic proceeding, that enhances existing solutions of today’s cooperation management by adding the key success components: inter-organizational process identification and process integration.

# Managing Complex Systems

Theme: Product and Systems Design  
Chair: Summers, Joshua

## A META MODEL OF THE INNOVATION PROCESS TO SUPPORT THE DECISION MAKING PROCESS USING STRUCTURAL COMPLEXITY MANAGEMENT

**Kortler, Sebastian; Lindemann, Udo**

Technische Universität München, Germany

The innovation process is characterized by numerous interactions of numerous domains. Cyclic interdependencies intensify the pressure in terms of quality and schedule, causing shortened testing phases, frequent releases of new models, and thus hardly calculable risks. Structural Complexity management is established in order to avoid wrong decisions, instable processes and error-prone solutions. Therefore, Structural Complexity Management evaluates system’s characteristics by analyzing system’s underlying structures across multiple domains, condensing each single analysis into one big matrix that represents multiple domains at a time.

Identifying suitable perspectives, generating suitable models and using suitable analyze criteria are the challenges in this field.

In order to support the manufacturing of innovative products and thus the evaluation and interpretation of the system’s underlying structure this paper proposes a meta model. The created model describes what kinds of entities arise during the innovations process and how they interact with each other. The meta model is needed to ensure a systematically basis for Structural Complexity Management.

## BALANCING INTERNAL AND EXTERNAL PRODUCT VARIETY IN PRODUCT DEVELOPMENT

**Graessler, Iris**

Robert Bosch GmbH, Germany

Applicability of “Mass Customization” to mechatronic systems is proven by various product examples in automobile industry. For example, chassis performance is adjusted to the driver’s specific wishes or to present driving circumstances, such as road condition. As a basic principle, hardware forms functional framework while software defines specific functional contents and characteristics.

Balancing internal with external product variety emerges as critical success factor in this context. From external point of view, as much variety shall be provided as end customers are willing to pay for. From internal point of view, each product variant induces consequential costs and thus lessens profitability. In this contribution, a methodology of designing a construction kit for customer specific solutions based on classic German design theories is proposed. A modular product architecture forms the logical context of the construction kit for customer specific solutions. Deduced products are individualized by selection and connection of standardized, discretely and continuously varying components. Thus economic variation required by customers becomes feasible also on a high technical level.

## ON THE APPLICABILITY OF STRUCTURAL CRITERIA IN COMPLEXITY MANAGEMENT

**Biedermann, Wieland; Lindemann, Udo**

Technische Universität München, Germany

Companies face challenges due to increasing complexity through shorter product life cycles, manifold customer requirements, more solution options and discipline-spanning collaboration. During the development of complex systems efficient tools for analysis and for assessment of solutions are necessary. A common approach is structural analysis, which can be applied in early development phases. System structures are analyzed with structural criteria such as cycles and clusters. Manifold criteria have been introduced in graph theory and applied in complexity management. In industrial applications suitable criteria have to be chosen. In research the significance of the criteria has to be shown. Based on an extensive literature review we show applications of structural criteria in complexity management. We derive requirements onto structural criteria from the applications. We show methods to prove the applicability of the criteria. Researchers get tools for proving and assessing the significance of structural analyses. More effective analyses can be developed. The quality of technical solutions increases and manifold solutions can be developed.



# Engineering Economics and Management

Theme: Design Methods and Tools  
Chair: Goh, Yee Mey

## ECONOMIC IMPACT ESTIMATION OF NEW DESIGN METHODS

**Koppe, Roland (1); Häusler, Stefan (1); Poppen, Frank (1); große Austing, Stephan (2); Hahn, Axel (2)**

1: OFFIS Institute for Information Technology, Germany; 2: University of Oldenburg, Germany

New design methods and tools often promise large benefits for specific engineering tasks or whole engineering processes to make increasingly complex and sophisticated products possible. However, estimations for the pay-off of new methods or tools are based on gut feelings or rare expert knowledge. In this paper we present our approach for well-founded quantitative estimations for the economic impact of new methods or tools. We show the beginning of our methodology with an early experiment and the impact analysis for a case study of a design flow for electronic circuits.

## TOWARDS ASSESSING THE VALUE OF AEROSPACE COMPONENTS: A CONCEPTUAL SCENARIO

**Bertoni, Marco; Bertoni, Alessandro; Johansson, Christian**

Luleå University of Technology, Sweden

The development of complex products, characterized by long lifecycles and deep supply chains, requires enhanced capabilities to assess, in an early design stage, the value of a solution not merely from a requirement fulfillment perspective. The paper proposes a conceptual scenario, described in terms of activities, inputs, outputs, actors and mechanisms, which details how aircraft components can be developed and assessed with a focus on their value contribution at system level. The scenario proposes a set of methodological and technological tools needed to enable value assessment in preliminary design, and has been created and preliminary validated together with major European aerospace manufacturers. The importance of being able to communicate the lifecycle value contribution of design solutions during the development work emerged clearly from the study. In this spirit, an approach to visualize such contribution directly in a 3D CAD model (across a set of value criteria, dimensions and drivers) has been proposed and it is currently under development.

## SYSTEM DYNAMICS MODELING OF NEW VEHICLE ARCHITECTURE ADOPTION

**Gorbea, Carlos Enrique; Lindemann, Udo; de Weck, Oliver**

Technische Universitaet Muenchen, Germany

This paper presents a system dynamics simulation model used to predict the market share penetration of hybrid (HEV) and battery electric vehicles (BEV) over time. The utility of the model for early design decision making stems from its ability to link key influencing factors such as: fuel price fluctuations, government incentives, customer network effects, vehicle cost of ownership/operation and initial retail price differences between alternative vehicle architectures to the internal combustion engine (ICE) reference architecture in a transparent mathematical formulation. The simulation model is set to the 2009 conditions of the light duty vehicle market in the United States and run for a period of ten years from 2009-2020. After 200 iterations with varying fuel prices, the simulation results predict that by 2020 market advances of hybrid cars will go from 4.5% to roughly 14% and electric cars from 0% to roughly 5% market share of new vehicles sold. The estimated figures presented are in line with previously published market analyst estimates. Additionally, the model has the added advantage of experimenting on how influencing factors affect the simulation results.

# Change Management

Theme: Design Processes  
Chair: Ahmed-Kristensen, Saeema

## INTEGRATED SYSTEM AND CONTEXT MODELING OF ITERATIONS AND CHANGES IN DEVELOPMENT PROCESSES

**Langer, Stefan; Herberg, Arne; Körber, Klaus; Lindemann, Udo**

TU München, Germany

Cycles play a decisive role in innovation and development processes. Iterations and engineering changes as one perspective on cycles have a major influence on both value generation as well as resource consumption within the process. While several initiatives are addressing this field of research, methods for coping with iterations and engineering changes more effectively and efficiently are still needed. This research contributes an explanatory model of cycles, iterations and changes that integrates both a system perspective and a context perspective on the development process. The modeling concept is evaluated by modeling examples from the development process of a SAE Formula student race car. The results show that the model allows for (1) a more precise analysis of iterations and changes, (2) for the derivation of hypotheses for handling iterations and changes and (3) for a subsequent operationalization.

## INDICATING THE CRITICALITY OF CHANGES DURING THE PRODUCT LIFE CYCLE

**Behncke, Florian Hans Georg; Lindemann, Udo**

Technische Universität München, Germany

As technical changes account for a significant part of the efforts like cost and time in product development and result from failures, which mainly appear after the Start of Production (SOP), change management need to consider further life cycle phases to indicate the criticality of changes. With Original Equipment Manufacturers (OEM) concentrating on their core competences, suppliers are increasingly involved in the change process, which is challenging the established models for the evaluation of changes. This paper presents a model for indicating the criticality of changes, which is based on a product life cycle model and a change process including the change transmission by cause-effect relations. On that basis, a literature-based discussion of indicators leads to the deduction of two alternative indicators. The combination of those indicators finally enables the indication of the criticality of a change during the product life cycle through the affected life cycle phases and the organisational interfaces, which are the basis of the developed indication model.

## INFORMATION MODELS USED TO MANAGE ENGINEERING CHANGE: A REVIEW OF LITERATURE 2005-2010

**Ahmad, Naveed; Wynn, David C; Clarkson, John**

University of Cambridge, United Kingdom

Engineering change is a significant part of any product development programme. These changes can arise at many points throughout the product life-cycle, resulting in rework which can ripple through different stages of the design process. Managing change processes is thus a critical aspect of any design project, especially in complex design. Through a literature review this paper shows the diversity of information models used by different change management methods proposed in the literature. The papers are discussed and a classification framework for organising these change management approaches is presented.

## CHARACTERIZING THE DYNAMICS OF DESIGN CHANGE

**Siddiqi, Afreen (1); de Weck, Olivier L (1); Robinson, Bob (2); Keller, Rene (2)**

1: Massachusetts Institute of Technology, United States of America; 2: BP

Engineering design changes play an important role in improving the technical design and ensuring eventual success of the system. Most of the research related to design change has been traditionally focused on studying the management of the change process, prediction of change propagation and dynamics of rework in projects. This study conducts an empirical investigation of engineering design changes, as described through the attributes of change requests volume, costs, and location using a large dataset of an actual multi-year, multi-billion engineering project. A few theoretical generalizations are proposed regarding the dynamics of change volume and costs. The results of the data analysis are used to illustrate how knowledge of meta-change activity and attributes can be used both for informing resource allocation and planning decisions for project management, and improving system design.

Fossil Dot Com



**Charles Nielsen**  
*Director R&D  
DONG Energy*

Abstract

Since the start of the industrial revolution in 1800, with breakthrough innovations in iron production, textile industry and the steam engine, society has sustained incredible growth and transformation. During the 200 years, worldwide individual productivity has grown more than 32 times, and the transformation has moved 50% of us to live in cities, whereas a mere 3% dwelled in cities in 1800. However, this 200 year long fossil fuelled bubble is coming to an end, which affects societies around the world and the way we design products and services for these societies beyond imagination. With rich technological examples from his background as director of the innovation centre at DONG Energy, Charles Nielsen will discuss the impact of upcoming changes to the backbone of industry: the energy supply.

DONG Energy has an ambitious strategy of changing the energy supply from 15% to 85% renewable energy before 2040. Embodiment of the corporate strategy into designs including urban design, bio refineries, offshore wind, sun and electric vehicles will serve as a platform for describing design challenges of the future - A future where society at large becomes the most important stakeholder demanding sustenance.

Management gurus have taught us for the last 20 years that in the end we all are delivering products and services to end users. This may still hold true; however, we now need to learn that we all are nothing but subsidiary companies of the nature.

Biography

Charles Nielsen is head of Group R & D and director of the innovation centre in DONG Energy, Denmark's largest energy utilities company. Through these functions, he is responsible for corporate development in a long-term perspective. Specific areas of focus include new business development and transition of the company; from a fossil-based energy paradigm into one predominantly based on renewable energy sources.

Charles' strong interest in integrating renewable energy into the energy system is pursued through active involvement in regulatory, corporate and academic spheres, as technology is only one out of several degrees of freedom available to the designers of a renewable energy system. Concrete means for this integration include bio-refinery technologies, integration of renewable energy, new customer demands and applications as well as partnerships with universities and knowledge institutions.

Through Charles impressive 20 year long track record within the energy industry, he has played a central role in developing and implementing many break-through innovations. A recent example is the development of a technology to produce bio-ethanol from straw, the so-called 2nd generation bio ethanol. Close collaboration with national and international universities, as well a leading component manufacturers, plays a significant role in the development work. On an everyday basis they provide invaluable intellectual and practical inspiration for the development of sustainable new business concepts – Something considered nice to have 5 years ago, but now a cornerstone in any sound energy companies strategy.

When Machines Design Machines!



**Peter Cochrane**  
*OBE, BSc, MSc, PhD, DSc, CGIA, FREng, FRSA, FIEE, FIEEE  
Co-Founder, Chairman & Director  
Cochrane Associates*

Abstract

Until recently we were the sole designers, alone in the driving seat making all the decisions. But, we have created a world of complexity way beyond human ability to understand, control, and govern. Machines now do more trades than humans on stock markets, they control our power, water, gas and food supplies, manage our elevators, microclimates, automobiles and transport systems, and manufacture almost everything.

It should come as no surprise that machines are now designing machines. The chips that power our computers and mobile phones, the robots and commercial processing plants on which we depend, all are now largely designed by machines. So what of us - will be totally usurped, or are we looking at a new symbiosis with human and artificial intelligences combined to realise the best outcomes possible.

In most respects we have no choice! Human abilities alone cannot solve any of the major problems that confront our species, and machine intelligence is now an imperative. To get the very best results we have to use computer modelling, visualisation and decision support. This also turns out to be a route to new materials, processing, production and thinking that promises to revitalise our industries and realise sustainable solutions. It may even turn out to be a new industrial revolution.

Far from being taken out of the design loop, we will find ourselves with a new and more vital role...

Biography

As a seasoned professional with over 40 years of hands on management, technology and operational experience, Peter has been involved in established companies at an operational level, the creation and deployment of new technologies, products and management systems, plus the transformation of corporations, and the starting of many new businesses.

His career in BT saw a progression from R&D engineer before to Head of Research and then CTO. With a 1000 strong team engaged in studies spanning optical fiber, fixed and mobile networks, system, product, and human design, Peter reported direct to the main board and was responsible for new product development, networks, systems, eCommerce, eLogistics and many other new businesses.

Peter has also been employed in the defence, logistics, travel, retail, energy, healthcare, transport, pharma, and consulting sectors. As an investor and entrepreneur he has also engaged in the founding of new companies, and global investments.

He was appointed as the UK's first Prof for the Public Understanding of Science & Technology @ Bristol in 1998. A graduate of Nottingham Trent and Essex Universities, Peter has received notable recognition with the Queen's Award for Innovation & Export in 1990, numerous Honorary Doctorates, and was awarded an OBE in 1999 for contributions to international communications.

Methods for Appraising Design Research

Theme: Design Theory and Research Methodology  
Chair: Chakrabarti, Amaresh

A FRAMEWORK FOR COMPARING DESIGN MODELLING APPROACHES ACROSS DISCIPLINES

Eisenbart, Boris; Gericke, Kilian; Blessing, Lucienne

Université du Luxembourg, Luxembourg

Design models are important means for the representation of information in product development processes. Designers use design models to visualise and communicate their ideas to other members of a design team, the project manager or a costumer. Communication through design models between experts from different domains is often hindered by different terminology and different ways of modelling information. Potential consequences are design flaws, which may lead to time-consuming iterations, project failure and – if undetected – to problems during production or use. In order to enhance the communication through design models across domains, and to address the mentioned problems, a basic understanding of similarities as well as differences between modelling approaches needs to be established. For that purpose, this paper discusses different design states which represent a distinct level of available information in the development process. They are derived through comparing different design models proposed in literature and provide the basis for a detailed comparison of modelling approaches across domains. Further, first insights into different ways of modelling are discussed.

COMPARING DESIGNING ACROSS DIFFERENT DOMAINS: AN EXPLORATORY CASE STUDY

Kan, Jeff Wai Tak (1); Gero, John S (2)

1: Taylor's University, Malaysia; 2: Krasnow Institute for Advanced Study, Fairfax, VA, USA

This paper presents the results of comparing designing across different domains. It is claimed that designing involves ontological issues and processes that can be observed and appear across all domains in contrast to the belief that designing is unique to its domain. A case study of designing in three different domains, architectural design, software design, and mechanical design, was conducted. A concise qualitative analysis of the session is presented before reporting results from quantitative measurement of the design issues and processes in the three design sessions. We found differences in terms of design issues and processes in the three design sessions. The results from this case study support the claim that an ontologically based approach allows for comparisons of designing across multiple domains.

UNDERSTANDING THE WORLDS OF DESIGN AND ENGINEERING – AN APPRAISAL OF MODELS

Gudem, Martin; Boks, Casper; Welo, Torgeir

Norwegian University of Science and Technology, Norway

Using product innovation models as reference, this study presents barriers preventing integration between the worlds of product design and engineering. Models illustrating workflow within both communities are compared, with the intention of revealing parallels and incompatibilities. Findings from research in design, cognitive theory, and innovation theory are then applied, seeking to explain why barriers exist. The study indicates a tendency in the design community towards seeing product development in a wider perspective, while engineers appear more concerned with technical detail. Furthermore, designers and engineers tend to have their own opinions about what design really is, what documentation forms are needed, how to tackle a problem, and why innovation models are needed. Seeking to develop mutual understanding, which is necessary for balancing 'soft' qualitative attributes and 'hard' performance requirements in product development, is challenging, since both groups possess limited capabilities in terms of recognizing or understanding what attributes are important to the other party.



CONDUCTING PRELIMINARY DESIGN AROUND AN INTERACTIVE TABLETOP

Kendira, Atman; Gidel, Thierry; Jones, Alistair; Lenne, Dominique; Barthès, Jean-Paul; Moulin, Claude

Université de Technologie de Compiègne, France

Our work lies at the intersection of preliminary design and tabletop groupware. We have constructed our own prototype, named the TATIN table, to begin developing applications for design teams. During the design of our system, through an extensive literature review we have identified the early preliminary design phase of a project to be the area where interactive tabletops would make the greatest impact. Next, we developed software for group brainstorming sessions and conducted extensive usability experiments using this software. During the experiments, we administered subjective questionnaires and obtained extensive video footage of the session. We present our techniques for the analysis of these videos and report our results on collaboration and communication in this environment.

HOW TO VALIDATE RESEARCH IN ENGINEERING DESIGN?

Barth, Alex (3); Caillaud, Emmanuel (1,2); Rose, Bertrand (1,2)

1: Universite de Strasbourg, France; 2: LGECO Strasbourg, France; 3: Syracuse university, USA

Research in engineering design is a rapidly growing field of interest with an increasingly complex and multi-disciplinary nature, and it has been difficult for researchers to structure its contents. This paper conducts a literature review of 71 publications from the past five years in the Journal of Research in Engineering Design. The goal is to look for correlations between types of research and the types of validation in hopes to improve the quality of research in engineering design and to aid researchers in the search for a common methodology. By analyzing the contents of each paper, a way of classifying the types of research and validation is developed. Due to a lack of application of research studies in real industrial settings, this paper also asks the question: is an industrial validation mandatory? The classification of papers in the field may provide clarification for understanding and potentially allow for some important distinctions in design methodology. The survey of the literature, combined with the results of this study, indicate that there is room for improvement in the field of research in engineering design, and this paper hopes to add support to that improvement.



DESIGN RESEARCH REFLECTIONS - 30 YEARS ON

Wallace, Ken (1); Hales, Crispin (2)

1: University of Cambridge, United Kingdom; 2: Hales and Gooch Ltd

At ICED 83 in Copenhagen in 1983, we presented a paper describing the start of a large participant observation study in industry. We expressed our early views about the issues that needed to be addressed by design research. At ICED 85 in Hamburg we presented an interim report on the project, and at ICED 87 in Boston a summary of the final results. Subsequently one author continued to work in academic design research in the UK and the other moved into accident investigation in the USA. Looking back, it is interesting to reflect on what we learnt from our design research project and from design research in general. We observe that despite all the advances in design research, many engineering companies either ignore well-established methods or are unaware of them. We also observe there are many instances of failures to address the well-established engineering fundamentals in both practice and research. A particular engineering failure has been selected as an example, from many hundreds investigated, to highlight typical shortcomings, even in a long-established company that prides itself on its design capability.



# Product Families

Theme: Product and Systems Design  
Chair: Mortensen, Niels Henrik

## A METHODICAL APPROACH FOR DEVELOPING MODULAR PRODUCT FAMILIES

**Krause, Dieter; Eilmus, Sandra**

*Hamburg University of Technology, Germany*

To offer individualised products at globally marketable prices, Institute PKT’s integrated approach for developing modular product families aims to generate maximum external product variety using the lowest possible internal process and component variety. Methodical units of design for variety and life phases modularization support the creation of modular product structures on the level of conceptual design. During embodiment design modular attributes are enhanced through module and interface design according to corporate needs integrating further requirements on product properties. The methodical approach is explained in example of a product family of herbicide spraying systems.

## BROWNFIELD PROCESS FOR DEVELOPING OF PRODUCT FAMILIES

**Lehtonen, Timo (1); Pakkanen, Jarkko (1); Lanz, Minna (1); Järvenpää, Jukka (2); Tuokko, Reijo (1)**

*1: Tampere University of Technology, Finland; 2: Finn-Power Oy, Finland*

This paper represents a development process of product families in a case where already available designs are emphasized. This can be called as a brownfield process. Tools, which support the individual steps of brownfield development projects, do exist. In this paper it is described how these tools, methods and procedures can be used to cover a whole development process of a product family. The development of a product family was divided into five steps: setting of goals, developing of a generic element model, analyzing the customer requirements, analyzing the minimum variation and describing the resulted product structure. In the first four steps existing tools were used. In the fifth step new description method, Product Structuring Blue Print (PSBP), for describing a product structure was represented. PSBP shows how items are related on assemblies, how modules include assemblies, how modules are realized, and what customer requirement is connected to each module. PSBP helps in creating the view of the significance of the product structure solution principles. PSPB gives also a response to how product structuring decisions have to be made.

## PRODUCT PLATFORM AUTOMATION FOR OPTIMAL CONFIGURATION OF INDUSTRIAL ROBOT FAMILIES

**Tarkian, Mehdi (1); Ölvander, Johan (1); Feng, Xiaolong (2); Pettersson, Marcus (2)**

*1: Linköping University, Sweden; 2: ABB, Sweden*

Product platform design is a well recognized methodology to effectively increase range and variety of products and simultaneously decrease internal variety of components by introducing modularization. The tradeoff between product performance and product family communality has to be carefully balanced in order to meet market requirements and for the company to simultaneously remain competitive. This paper will present a framework based on high fidelity analyses tools to concurrently optimize an industrial robot family as well as the common platform. The product family design problem is formally stated as a multi-objective optimization problem, which is solved using a multi-objective Genetic Algorithm.

## PROACTIVE MODELING OF MARKET, PRODUCT AND PRODUCTION ARCHITECTURES

**Mortensen, Niels Henrik; Hansen, Christian Lindschou; Hvam, Lars; Andreasen, Mogens Myrup**

*Tecnical University of Denmark, Denmark*

This paper presents an operational model that allows description of market, products and production architectures. The main feature of this model is the ability to describe both structural and functional aspect of architectures. The structural aspect is an answer to the question: What constitutes the architecture, e.g. standard designs, design units and interfaces? The functional aspect is an answer to the question: What is the behaviour or the architecture, what is it able to do, i.e. which products at which performance levels can be derived from the architecture? Among the most important benefits of this model is the explicit ability to describe what the architecture is prepared for, and what it is not prepared for - concerning development of future derivative products. The model has been applied in a large scale global product development project. Among the most important benefits is contribution to:

- Improved preparedness for future launches, e.g. user interface and improved energy efficiency
- Achievement of attractive cost- and technical performance level on all products in the product family
- On time launch of the first generation of the product family

## STRATEGIC PLANNING FOR MODULAR PRODUCT FAMILIES

**Jonas, Henry; Krause, Dieter**

*Hamburg University of Technology, Germany*

Highly customised products mostly lead to an increasing complexity for the producing company. Two commonly known design approaches to reduce the internal complexity of a product family are design for variety and modularisation. However, for many application cases it is desirable to consider an optimisation of the variety already in the product planning phase affecting a wide range of products. The approach presented in this paper uses a representation both of the structure of products and economic key figures. Using this method, different strategic scenarios of the product program can be planned and assessed to each other. The derivation of strategies for the future and their evaluation uses both economic key figures and the technical conceptualisation of platform components.



# Digital Modelling and Behavioural Simulation

Theme: Design Methods and Tools  
Chair: Chen, Wei

## SIMULATION BASED GENERATION OF AN INITIAL DESIGN TAKING INTO ACCOUNT GEOMETRIC DEVIATIONS AND DEFORMATIONS

Walter, Michael; Breitsprecher, Thilo; Gruber, Georg; Wartzack, Sandro

University of Erlangen-Nuremberg, Germany

The success of a product’s development is essentially affected by its functionality. So the product developer has to ensure the functionality as early as possible. Since this usually can’t be achieved with the first design several iterations are needed to modify the design.

The product’s functionality depends largely on the interaction of its components and their geometries. So geometric deviations of these components need to be taken into account. These deviations can result e.g. from manufacturing discrepancies or being operation-depending like deformations.

This paper presents an approach which enables the product developer to determine an initial design proposal that fulfils its function. So no time- and money-consuming iterations are needed. Therefore the approach uses methods and tools like tolerance allocation, topology optimization and parameter optimization at an early stage. The tolerance allocation is needed to define the functional requirement of the non-ideal components. The optimization tools are used to create the initial design proposal fulfilling the functional requirement. A case study of a non-ideal scissor-type lift table illustrates the approach.

## GEOMETRIC MANIPULATION METHOD FOR EVALUATION OF AESTHETIC QUALITY IN EARLY DESIGN PHASES

Stoll, Tobias; Stockinger, Andreas; Wartzack, Sandro

University of Erlangen-Nuremberg, Germany

Whenever products are manufactured there are deviations from the ideal geometry defined in the CAD-system. In this report a prototype is presented which allows a user to set up non-ideal visualizations of slightly deformed parts easily and quickly. The method can be used in the early stages of product development to ensure that aesthetic quality is taken into account before a real product has been manufactured. Very important key criteria for the appearance of several products, e.g. automotive car bodies or consumer products are gap and flush measurements. Therefore the developed method allows an intuitive and fast way to generate visualizations which can be used in design reviews. By using efficient data structures for the calculation of the deformation it is possible to change the shape of objects interactively during the design review itself. A case study has been performed to show that it’s possible to generate simulations which are close to the output of manufacturing simulations.

## EVALUATION OF SOLUTION VARIANTS IN CONCEPTUAL DESIGN BY MEANS OF ADEQUATE SENSITIVITY INDICES

Eifler, Tobias; Johannes, Mathias; Roland, Engelhardt; Marion, Wiebel; Hermann, Kloberdanz; Herbert, Birkhofer; Bohn, Andrea

Technische Universität Darmstadt, Germany

Every engineering product is exposed to a multitude of uncertain influencing factors during the different stages of its life cycle. While much effort is invested to deal with this uncertainty during production and use, it often is not adequately taken into account in product development. Moreover, especially in the early design stages well-know methods of probabilistic uncertainty analysis often cannot be applied adequately. They necessitate an elaborated concept or even a mathematical description of the underlying relationships. In this contribution an approach to assess the influence of different design parameters in a network of physical effects is proposed, based on available methods for sensitivity analysis. The different indices are examined with regard to their applicability during Conceptual Design. Quantitative, but usually highly complex methods are thereby complemented by qualitative ones. In this way, the approach allows to deal with the changing as well as usually low level of information and supports the evaluation of concepts on an abstract level of description.

## COMBINING NARRATIVE AND NUMERICAL SIMULATION: A SUPPLY CHAIN CASE

Hansen, Mette Sanne; Ladeby, Klaes Rohde; Rasmussen, Lauge Baungaard; Jacobsen, Peter

Technical University of Denmark, Denmark

Strategic simulation is the combination of narrative and numerical simulation and can be used as a tool to support strategic decision making by providing different scenarios in combination with computer modelling. The core of the combined simulation approach (CSA) is to make it possible for decision makers to systematically test several different outputs of possible solutions in order to prepare for future consequences. The CSA can be a way to evaluate risks and address possible unforeseen problems in a more methodical way than either guessing or forecasting. This paper contributes to the decision making in operations and production management by providing new insights into modelling and simulation based on the combined narrative and numerical simulation approach as a tool for strategy making. The research question asks, “How can the CSA be applied in a practical context to support strategy making?” The paper uses a case study where interviews and observations were carried out in a Danish corporation. The CSA is a new way to address decision making and has both practical value and further expands the use of strategic simulation as a management tool.

## EVALUATION OF DATA QUALITY IN THE CONTEXT OF CONTINUOUS PRODUCT VALIDATION THROUGHOUT THE DEVELOPMENT PROCESS

Reitmeier, Jochen; Paetzold, Kristin

Universität der Bundeswehr München, Germany

Focus of current research activities is to develop a holistic and capable method for the continuous validation of product properties throughout the development process by the means of simulations to significantly reduce development cycles and to increase product quality.

Simulation methodology is an appropriate device to gain knowledge about real systems through models. However, it will be absolutely necessary to indicate which input data the simulation results are based on in order to prevent systematic errors and avoid implying a precision that does not exist. Data quality must be pre-defined depending on the current process step if simulations are to be executed efficiently. Therefore, the objective must be to be able to describe the available data basis and to give methodical support to assist engineers at the decision-making process as far as necessary. Consequently more goal-oriented iteration loops can be carried out resp. the further working process can be suitably designed in terms of concurrent engineering.

## SUPPORTING INCLUSIVE PRODUCT DESIGN WITH VIRTUAL USER MODELS AT THE EARLY STAGES OF PRODUCT DEVELOPMENT

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1: BIK - Institut für integrierte Produktentwicklung, Germany; 2: TZI - Technologie-Zentrum Informatik und Informationstechnik, Germany

The aim of inclusive product design is to successfully integrate human factors in the product development process with the intention of making products accessible for the largest possible group of users. In order to meet the challenge of inclusive product design, the involvement of human users in all phases of the development process has so far been an efficient approach. Yet, such ergonomics evaluation experiments that employ a versatility of user groups are not only complex, but can be very time and cost-intensive. Therefore, virtual user models (VUM) have been proposed for supporting certain phases of the product development process.

In this paper a model-based design approach is proposed, which supports inclusive design of consumer products at the early stages of product development. Accordingly the objective of this paper is to explore how virtual user models can be used for inclusive product design and to conceptualize user interfaces of consumer products in such a way that even the needs of users with physical impairments are fully considered, without the necessity of incorporating users in the traditional way.

# Design Information and Product Life Cycle

Theme: Design Information and Knowledge  
Chair: Malmqvist, Johan Lars

## LEARNING FROM THE LIFECYCLE: THE CAPABILITIES AND LIMITATIONS OF CURRENT PRODUCT LIFECYCLE PRACTICE AND SYSTEMS

**Gopsill, James Anthony; McAlpine, Hamish Charles; Hicks, Ben James**

*University of Bath, United Kingdom*

Design teams within the High Value Low Volume (HVLV) industry are facing ever-increasing challenges in developing new products. This has been largely due to the paradigm shift towards Product-Service Systems (PSS), the growing importance of demonstrating Corporate Social Responsibility (CSR) and stricter environmental legislation. With the variant nature of the design process within HVLV industry and the longevity of the product life-cycles, it is recognised that learning from previous products is essential for new product innovation and development. The ability to do this depends upon the company's product lifecycle practice and systems, and its inherent capability/limitations. To explore these issues, the paper maps the data and information flow alongside the systems involved, onto a generalised product lifecycle generated from an extensive literature review. The map is then used to analyse current product data lifecycle practice and considers its capability to provide design teams in the HVLV industry with sufficient data and information with regards to the lifecycle phases of existing products to inform variant product design.

## KNOWLEDGE CONFIGURATION MANAGEMENT FOR PRODUCT DESIGN AND NUMERICAL SIMULATION

**Badin, Julien (1); Chamoret, Dominique (1); Gomes, Samuel (1); Monticolo, Davy (2)**

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We focus on industrial design and simulation processes especially in automotive and aerospace areas. Designers use engineering models such as CAD (Computed Aided Design) and CAE (Computed Aided Engineering) models to optimize and streamline the engineering process. Each expert model is driven by parameters, expert rules, mathematic relations which are shared by several users and in several different domains (mechanical, thermal, acoustic, fluid, etc) and exploited at the same time in a concurrent engineering context. It is the basis of an imperfect collaboration process due to the fact that existing tools do not manage encapsulated knowledge well and are unable to ensure that parameters and rules are consistent (same value of parameters for example) throughout different heterogeneous expert models. In this context, we propose an approach to manage knowledge using configurations synchronized with expert models which enable designers to use parameters consistently in a collaborative context. Our approach is called \*KCMModel (Knowledge Configuration Model): it allows capitalization, Traceability, re-use and consistency of explicit knowledge used in configuration.\*

## MANIFESTATION OF UNCERTAINTY - A CLASSIFICATION

**Kreye, Melanie E (1); Goh, Yee Mey (2); Newnes, Linda B (1)**

*1: University of Bath, United Kingdom; 2: Loughborough University, United Kingdom*

The aim of the research presented in this paper is to propose a classification of the manifestation of uncertainty to offer a basis for a shared understanding and characterization of the concept of uncertainty within the area of design research. During the past decade a growing number of papers about uncertainty have been published. These papers focus on different aspects and points of the design process and offer insights on different aspects of uncertainty. The research presented in this paper describes the manifestation of uncertainty and proposes a classification. The classification consists of context uncertainty arising from the situation circumstances, data uncertainty stemming from input information or data into a further process, model uncertainty resulting from the simplifications in models, and phenomenological uncertainty connected to the outcome of a process. Each of these categories is described in detail offering a basis for positioning specific research contributions published in previous ICED conferences. This offers a basis for the consideration of the appropriate uncertainty management methods.

## COMPARATIVE STUDY OF THEORETICAL AND REAL USES OF ECO-DESIGNED LAUNDRY DETERGENTS

**Chapotot, Emilie (1); Abi Akle, Audrey (1); Minel, Stéphanie (1); Yannou, Bernard (2)**

*1: ESTIA, France; 2: LGI, Ecole Centrale Paris*

Directions for use given by manufacturers of consumer products are often based on ideal conditions of use. However, each user is different and has complex user characteristics which may impact the directions of manufacturers and thus divert a product's primary functions. In this study we therefore propose examining this phenomenon of use in eco-designed laundry detergents. Initially designed to respect the environment, are they always environmentally-friendly in real conditions of use and what factors can reverse their benefits? After a state of the art in eco-designed laundry detergents and major criteria for use, we present the statistical analyses and tests which show the importance of knowing and modelling real uses so as to better design and adapt such products.

# Collaboration

Theme: Human Behaviour in Design  
Chair: Törlind, Peter

## REVIEW OF COLLABORATIVE ENGINEERING ENVIRONMENTS: SOFTWARE, HARDWARE, PEOPLEWARE

**Osborn, Jonathan (1); Summers, Joshua (2); Mocko, Gregory (2)**

*1: South Carolina Research Authority; 2: Clemson University*

This paper compares collaborative engineering environments that are reported in the literature with respect to three specific aspects: software, hardware, and peopleware configurations. A taxonomy is developed to fully describe each of the different environments. It is shown that no environment incorporates all different aspects. Using this taxonomy, an intersecting set of features from these environments may be used to develop future environments for customized purposes.

## SUPPORTING ANNOTATION-BASED ARGUMENTATION LINKING DISCURSIVE AND GRAPHICAL ASPECTS OF DESIGN FOR ASYNCHRONOUS COMMUNICATION

**Boujut, Jean-François**

*Grenoble Institute of Technology, France*

In this paper we will focus on distant collaborative design activities. In design graphic representations has always play an important role. If one look back in the history of engineering, graphic representations has always been strongly present. Drawings, sketches, mock-ups, and more recently digital representations (CAD, virtual reality, etc.) are commonly shared in design teams. For many years we have been studying the role of mediating objects in design teams, facilitating common understanding, knowledge elicitation and sharing. More recently we have focused on the argumentative side of design. Indeed, the discursive aspect of design is almost as important as the graphic one. In relation to these observations we discuss the concept of intermediary object, boundary object and transactive memory as a good theoretical framework. Today new technologies enable to rethink the mediating structures in distant collaborative work. Particularly we have studied the role of annotations for linking discursive and graphical aspects of design. This led us to develop an annotation plate-form we will present and propose to the discussion.

## SOCIAL MEDIA ENABLED DESIGN COMMUNICATION STRUCTURE IN A BUYER-SUPPLIER RELATIONSHIP

**Hölttä, Venlakaisa; Eisto, Taneli**

*Aalto University, Finland*

Improving design communication in product development networks can lead to a better design process. This paper presents a new design communication structure in the buyer-supplier relationship better serves the needs of networked product development compared to traditional communication structures in buyer-supplier relationships. Social media tools were used to create the new communication structure. Data was collected with case studies in the foundry industry. A simulation game was played to test the use of social media tools in buyer-supplier relationships. The results show signs of social media tools enabling improved situational awareness, improving transparency, widening the response base, which was used for community sourcing within the product development network, and new social spaces create collaboration possibilities that were not possible before. These benefits help improve, for example, the design by including more points-of-view than before and by preventing challenges in production by increasing the awareness of the upcoming design.

## COLLABORATIVE TRUST NETWORKS IN ENGINEERING DESIGN ADAPTATION

**Atkinson, Simon Reay (1); Caldwell, Nicholas H.M. (1); Maier, Anja M. (2); Clarkson, P. John (1)**

*1: Cambridge University Engineering Department, United Kingdom; 2: Department of Management Engineering, Technical University of Denmark*

Within organisations, decision makers have to rely on collaboration with other actors from different disciplines working within highly dynamic and distributed associated networks of varying size and scales. This paper develops control and influence networks within Design Structure Matrices (DSM); applying the Change Prediction Method (CPM) tool. It posits the idea of the 'Networks-in-Being' with varying individual and collective characteristics. [Social] networks are considered to facilitate information exchange between actors. At the same time, networks failing to provide trusted-information can hinder effective communication and collaboration. Different combinations of trust may therefore improve or impair the likelihood of information flow, transfer and subsequent action (cause and effect). This paper investigates how analysing different types of network-structures-in-being can support collaboration and decision-making by using the change prediction method as a way of scoping information propagation between actors within a network.

# Organising Collaborative Design Processes II

Theme: Design Organisation and Management  
Chair: Blanco, Eric

## COLLABORATIVE GLITCHES IN DESIGN CHAIN: CASE STUDY OF AN UNSUCCESSFUL PRODUCT DEVELOPMENT WITH A SUPPLIER

**Personnier, Hélène (1); Le Dain, Marie-Anne (1); Calvi, Richard (2)**

1: Grenoble-INP, G-SCOP Laboratory, France; 2: IREGE, Savoie University, Institute of Management, France

The focus of the firms on their core competencies associated with the increasing complexity of products due to an integration of various technologies has led to an extension of their New Product Development (NPD) activity across or- ganisational boundaries. The concept of \_design chain\_ defines the network of participants included in this extended activity of product development. This paper focuses on the collaborative design with suppliers within the design chain. It seeks to appraise the benefits of such collaboration on the product development performance. The approach pro- posed is based on the \_“glitch”\_ concept which enables us to tackle this issue from the opposite direction i.e. by identi- fying what happens when the collaboration with suppliers in design is absent. A case study analysis of an unsuccessful collaborative development with a supplier enables us to identify ten \_“glitches”\_ that would prevent from reaping the benefits of supplier involvement. Informed by findings from this exploratory case, a categorisation of the collaborative \_“glitches”\_ is proposed in order to analyse their impact on product development performance and to define preven- tive actions to avoid them.

## PACKAGING DESIGN IN ORGANIC FOOD SUPPLY CHAINS – A CASE STUDY IN SWEDEN

**Olsson, Annika (1); Lindh, Helena (1); Bertoluci, Gwenola (2)**

1: Lund University, Lund, Sweden; 2: Ecole Centrale Paris, Châtenay-Malabry, France

Packaging design is vital in the consumer product industry. Therefore, recent consumer preferences for locally pro- duced and organic food need to be met by product and package producers, in the package design process. The pur- pose of this study is to understand how package design is managed in food supply chains with a special focus on or- ganic and locally produced food in Sweden. It will also identify and elaborate on challenges met by small and medium sized food producers in the package design process. The results show deficiencies in organic food packaging design and the main issues can be divided into three main areas; package design and material selection, supply chain imbal- ance and knowledge aspects. The deficiencies are obvious for small local producers, but the study also indicate chal- lenges for national brand enterprises in focusing on eco-design and sustainable packaging solutions, since tradition and supplier decisions seems to dominate.

## INTEGRATION OF SUPPLIERS INTO THE PRODUCT DEVELOPMENT PROCESS USING THE EXAMPLE OF THE COMMERCIAL VEHICLE INDUSTRY

**Stephan, Nicole Katharina; Schindler, Christian**

University of Kaiserslautern, Germany

During the last years the duties and responsibilities of engineering units in the vehicle industry changed drastically. Time pressure, cost pressure and the complexity of products are constantly increasing. Furthermore, companies are working to a greater extent on an international basis. These reasons lead OEMs and sup- pliers to increase their cooperation and to undertake extensive efforts to optimize the processes in their supply chain. The research project aims at developing a workflow model which helps improving and accelerating the cooperation between clients and contractors in the product planning phase.

## CHALLENGES IN NETWORKED INNOVATION

**Maurer, Christiane; Valkenburg, Rianne**

The Hague University of Applied Sciences, Netherlands, The

The paper discusses an exploratory study within a longitudinal research project on open innovation, and specifically, the collaboration of two or more companies, named networked innovation. Nine companies were interviewed to gain information on their motivation to use networked innovation and the challenges they meet in doing so. They used two network types: elite circle and consortium. Challenges showed on different levels, concerning organization, project and actors. On organizational level, dominant factors determined whether a network could be started at all, mainly concerning companies within highly regulated sectors. On project level, the difficulties of networked innovation be- came obvious in the form of highly dynamic processes to which traditional methods do not apply any more. On actor level problems already known from intra-organizational teamwork showed up, augmented by the confrontation with different company cultures. The results are currently used as a base for further research by a multidisciplinary team investigating networked innovation at the three mentioned levels. A main goal of the project as a whole is to develop tools and methods for networked innovation.

# Design for Human Factors

Theme: Design for X, Design to X  
Chair: Sigurjónsson, Jóhannes B.

## DESIGNING FOR RESILIENCE: USING A DELPHI STUDY TO IDENTIFY RESILIENCE ISSUES FOR HOSPITAL DESIGNS IN A CHANGING CLIMATE

**Masko, Mary Lou (1); Eckert, Claudia M. (2); Caldwell, Nicholas H.M. (1); Clarkson, P. John (1)**

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Hospitals are facing a triple challenge - meeting mandatory climate change targets and refurbishing aging infrastruc- ture while simultaneously providing quality of care. With the potential of more frequent disruptive weather events, a UK government-funded project was launched in 2009 to investigate practical strategies for the National Health Service to increase its resilience to climate change. This paper presents the process of defining resilience by using the Delphi method and demonstrates its applicability within healthcare design. A Delphi survey is nearing completion which has determined the significant resilience issues and temperature ranges for ideal and critical conditions. Our preliminary findings identified six priorities that lead towards increasing resilience. Using the Delphi method can be a useful tool in clarifying the focus for healthcare design considerations.

## UNIVERSAL DESIGN AND VISUAL IMPAIRMENT: TACTILE PRODUCTS FOR HERITAGE ACCESS

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This article presents a pilot study carried out in the city of Barcelona on assistive resources applied to an itinerary of possible interest to visually impaired people. The objective of this study was to use qualitative research techniques to analyze the use of tactile maps, produced with 3D printing, in order to allow people to identify and memorize routes. This analysis was carried out using an evaluation model based on the principles of Universal Design (UD). Four visually impaired users participated in this initial study. They tried the different mock-ups, providing an experience in response to the main research questions:“Could 3D printing be a good technique for making tactile maps for all users, especially visually impaired users?” and “Could a visually impaired person use a map printed with this technique to learn a route to visit an accessible heritage site?”

## A CASE STUDY OF DESIGN FOR AFFORDANCE: AFFORDANCE FEATURES OF A SIMPLE MEDICAL DEVICE

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People interact with artifacts, either products or services, in their lives. These interactions are based on two-way com- munication between people and artifacts. The characteristics of artifacts that induce natural activities of people, af- fordances, play critical roles in making interactions successful and meaningful. Affordance features are the structural elements of artifacts that provide affordances. In this paper, affordance features of a simple medical device are thor- oughly studied. A task model has been developed based on the usage of a medical expert, and observation of activities of normal users has been conducted. Based on the structural elements of the device identified by state changes in user activity observation, affordance features have been identified. Then these features have been compared with func- tional features designed to provide the functions of the device. In this way, affordance features particularly designed to provide information- centered affordances were identified together with corresponding functional features.

## DESIGNING WITH A SOCIAL CONSCIENCE: AN EMERGING AREA IN INDUSTRIAL DESIGN EDUCATION AND PRACTICE

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In recent decades, a growing number of those in the industrial design profession have shown concern for socio-ethical issues and pondering the impacts of their work on the planet and its peoples. While mainstream industrial design education and practice still clearly focuses on product-centric innovation, the increasing involvement of designers in activities that advance the betterment of humanity is undeniable. Some university design programs immerse students in developing countries and disadvantaged neighborhoods to learn to co-design appropriate solutions with communi- ties. The professional design industry has also been supportive in engaging and contributing to this new area of social innovation. In line with this emergence of design for society, this paper reports on some of the studio projects at the Industrial Design Program at the University of New South Wales, which highlight design’s agency as a catalyst for social change. The studio briefs are discussed as case studies and the learning experiences gained and the reflections of stu- dents are analyzed and used as arguments for the continued and growing inclusion of social responsibility within the industrial design curriculum.



# Product Service Systems

Theme: Product and Systems Design  
Chair: Lindemann, Udo



## REPRESENTING PRODUCT-SERVICE SYSTEMS WITH PRODUCT AND SERVICE ELEMENTS

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This paper discusses the Product-Service Systems (PSS) representation method which configures product and service elements. PSS is composed of a number of product elements and service elements, and they are complicatedly connected to each other to satisfy customer needs. Therefore, it is of much significance to appropriately represent product and service elements and their relations in PSS. In this paper, a new PSS representation scheme to effectively configure the product and service elements is proposed. In the proposed PSS representation scheme, the service elements can be modelled with stakeholders – service provider/receiver, activities and associated product elements. The product elements are included in the service element and serve as media for realizing PSS. To realize the specific function, several service elements can be connected with flows that were identified in PSS functional modelling. Those flows can also be used to connect associated product elements. Finally, case study is conducted to investigate the applicability of the proposed PSS representation method to the real PSS design project

## ORTHOGONAL VIEWS ON PRODUCT/SERVICE-SYSTEM DESIGN IN AN ENTIRE INDUSTRY BRANCH

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Product/Service-Systems (PSS) is an emerging research area, with terms such as ‘functional sales’, ‘servicizing’ and ‘service engineering’ all contributing to the foundation and our current understanding of PSS as a phenomenon. The field is still in its formative stages and definitions, understandings and approaches to PSS are still fluid. Much of the literature in the field of PSS has, until now, focused largely on the actual transition from product to PSS and has typically resided in the field of engineering design. Symptomatic of the current literature is the concept of service as the adding-on of non-physical activities and relationships between supplier and customer. There is evidence in the literature, that multi-stakeholder approaches, customer activity understanding, actor-network charting and value chain collaboration are important factors to include in PSS strategies. However, actual case examples of these factors are sparse and limited to conceptual examples. This paper describes five orthogonal views on PSS design, fostering integrated product/service thinking across organizational boundaries, via a systematic approach to user-oriented product and service development.

## PRODUCT WITH SERVICE, TECHNOLOGY WITH BUSINESS MODEL: EXPANDING ENGINEERING DESIGN

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Looking back over the last decade, the importance of an expanded understanding of engineering design has been shared within the engineering design community. Presented concepts and methods to support such expansion include Functional Product Development, Service Engineering, and Product/Service-Systems (PSS) design. This paper first explains PSS design as a type of an expansion of the engineering design of a physical product. Secondly, it gives a review of PSS research and a projection of future research issues, also ranging out into untraditional fields of research. Finally, it presents a new promising concept beyond PSS design; via an integrated development of technology and business model. This can be of particular interest for further research, especially due to its high freedom for designers.

## PROPERTY RIGHTS THEORY AS A KEY ASPECT IN PRODUCT SERVICE ENGINEERING

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Product service systems (PSS) are a field of research which is supported by research in a large number of other areas. Product development and engineering design is the basis for most research projects but the economic theory has a major influence too. The theory of property rights has its origin in the new institutional economy. Different types of rights concerning a property are described systematically and can be distributed separately. Although the distribution of property rights in general is a key aspect for the PSS design, it has not yet been introduced into PSS considerations in a broad and systematic way. This papers aim is to close the gap and give a structured overview of the property rights theory and its potentials for PSS design. According to the procedure of the German VDI 2221 it is demonstrated how property rights considerations can support the different phases of a development process. Furthermore, it is demonstrated how property rights theory can support different goals in developing PSS and the author presents suggestions for a more differentiated look at the property rights distribution to improve the correlation with the requirements of PSS considerations.

## REPRESENTATION AND ANALYSIS OF BUSINESS ECOSYSTEMS CO-SPECIALIZING PRODUCTS AND SERVICES

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Recent dramatic changes in a mobile industry, initiated by smart phones, are drawing enormous attention to business ecosystems. A perspective to view firms as members of cross-industry ecosystem was first suggested by Moore for describing co-evolution behavior in high-technology business areas. Although an ecosystem has been pervasive in any industry at any time, today’s eco-systems are getting more horizontal and complex. This study develops a representation model of such complex ecosystems and a framework for analyzing interrelated productivity of ecosystem members. The proposed model especially emphasizes interdependency between product and service offerings that ecosystem members cooperatively deliver. This interdependency determines the interrelation between members’ productivity, and finally sustainability of a whole ecosystem. This study describes a general procedure for representing and analyzing an ecosystem and discusses the difference between the traditional and smart phone mobile ecosystems based on the result of the analysis.

## A FRAMEWORK FOR DESIGNING PRODUCT-SERVICE SYSTEMS

**Annamalai Vasantha, Gokula Vijaykumar; Hussain, Romana; Roy, Rajkumar; Tiwari, Ashutosh; Evans, Stephen**

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In this competitive globalizing scenario, manufacturers are adopting a strategy of bundling products and services into an integrated solution to create sustainable competitive advantage. Servitizing manufacturers are increasingly transforming their processes and practices to build product-service systems (PSS). During this transformation they require substantial support to face stringent challenges. Research in the PSS domain is heading towards the development of a design theory and methodology that facilitates the systematic creation of viable PSS conceptual designs. In this paper, various proposed design methods are reviewed and research gaps are summarized. Primarily, it has been observed that the importance of the capabilities of the stakeholders involved in designing PSS has not been noted in the proposed methods. Regarding this capability view point, a framework for designing PSS has been proposed. This framework highlights the important features required in designing PSS such as co-creation, responsibilities and competences. Every step in the framework has been explained with a case study involving laser system used for manufacturing cutting operation.

Design and Business Models

Theme: Design Organisation and Management  
Chairs: Eppinger, Steven; Lee, Burton H.

KNOWLEDGE MANAGEMENT CHALLENGES IN NEW BUSINESS DEVELOPMENT - TRANSITION OF THE ENERGY SYSTEM

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The empirical study this paper is based upon, aimed to identify and describe knowledge management challenges, throughout the new business development process. This paper reports findings from the study, as well as the framework used for analysing the KM challenges, which can be applied to other case studies for comparison. Six interviews and 2 full-day workshops, gathering the perspectives of 76 people from an energy-utilities company forms the empirical background of the study. Six categories of knowledge management challenges were identified and, within each, central issues were extracted and changes throughout the new business development process investigated. Significant differences from the early to the late stages of this process were identified, including; shift from personal to codified knowledge transfer and need for supporting integration of knowledge from diverse domains better in the early phases. Furthermore, two new roles of the early phase, besides instigating projects, were found. This study contributes to the development of support tools for knowledge management in industry and to research with a deeper understanding of the new business development process.

BUSINESS MODEL DESIGN METHODOLOGY FOR INNOVATIVE PRODUCT-SERVICE SYSTEMS: A STRATEGIC AND STRUCTURED APPROACH

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The business model is receiving considerable attention these days as companies achieve great success, or suffer damaging failure, by changing their way of doing business. The present study aims to provide a structured methodology for business model design. At the core of the methodology lies a design template with which a current business model can be analyzed or reinvented in a systematic manner. The template consists of a set of predefined building blocks that describes a business model's strategic patterns and/or constituent elements, which building blocks were collected and verified through an investigation into more than one hundred real-world business model cases. In addition to the design template, a framework for new business model design also is provided. With the help of the representational schemes and procedures therein defined, one can design a business model in a more structured way. The framework is illustrated by means of a case study of an apparel company that set out to commercialize its newly designed product-service system concept.

THE CENTRAL ROLE OF EXPLORATION IN DESIGNING BUSINESS CONCEPTS AND STRATEGY

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Design thinking is described as a combination of thinking and acting that leads to new solution possibilities for design problems. Though traditionally linked to the design of objects and services, it can be applied to organizational processes as well. This paper examines design thinking in developing a new business, focusing on the business concept and strategy formation in the start-up phase of the company. How and what elements of design thinking are manifested in the process of designing a business concept and forming a strategy? What is the importance of these elements in this process? The results reveal the experimental and iterative nature of developing the business concept and strategy. In addition, these organizational processes were strongly influenced by the product offering, stakeholders, and environment that the company operated in. While the results highlighted the importance of emergence, they also illustrated a need for structure and planning, thus reminding of the need of balancing between the two. Overall, the results suggest that many of the fundamental elements of design thinking are found in the development process of a company.

BUSINESS PLANS INFORMED BY DESIGN

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Today the value created by applying design at a business model and innovation level as opposed to a design and process level is marginal. Interviews with product developers from academia and industry suggest this is due to a lack of design perspective when formulating and evaluating business plans. To remedy this, we propose including Design Quality Criteria drivers in the formulation of business plans. While auditing entrepreneurial business plans and design briefs content gaps were revealed between them. Strategy and context differences as well as a negative correlation between investors' business plan valuation and the plans process content were found. This suggests that investors prefer plans with strategy and context descriptions to plans with high or unknown execution risk. We also found significant differences in structure and innovation content for the following polar opposite innovation types. These were the design of products based on sustainable and on disruptive technologies. In conclusion, we recommend a procedure to align and translate business plan content into inspirational design briefs for enhancing design concept synthesis performance.

DESIGNING A PROCESS FOR A MONOPOLY TO TRANSFORM TO A FREE MARKET COMPETITOR - THE SWEDISH PHARMACY SYSTEM

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The purpose of this paper is to examine how a political driven transition of a large company, Apoteket AB in Sweden with 12,000 employees – the pharmacy state monopoly – can be managed to a free market competitive player. The reregulation process, with a great variety of stakeholders involved, has since 2006 been followed, documented and analyzed. In the domain of pharmacy products and services – essential for health and well-being – a design and innovation process must be handled with care for balancing pharmaceutical and business strategies. The research contribution and expected learning outcome of this paper is to give insights; first on processes and methods for organizational designs and transformation; second to get experience from designing and implementing a management strategy to lead the reregulation to success; and third to get knowledge on how traditional professional roles can be changed and developed by designing a process with clear goals, conscious learning and a communicative strategy.

INFLUENCE OF THE TIME PERSPECTIVE ON NEW PRODUCT DEVELOPMENT SUCCESS INDICATORS



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Understanding the underlying reasons for new product development (NPD) success is central for effective NPD management. However, difficulties related to estimating to what extent the objectives are being fulfilled and assessing the trade-offs between different project goals makes the NPD process challenging and risky. It is hence crucial for companies to be able to effectively measure their success. Furthermore, these success indicators might be dynamic as they change depending on where a product is in its lifecycle. In this paper, we investigate the success criteria during different phases of the product lifecycle, in order to determine the appropriate sets of metrics to be used for assessing NPD success during each lifecycle phase. A case study was carried out by investigating 28 companies from Canadian and Danish industries. The data collection was carried out through the use of surveys and interviews with relevant product development managers. The outcomes showed that managers do perceive the success of NPD differently depending on the time perspective. A summary of metrics for measuring success during each product lifecycle phase is given.

# Early Stage Design

Theme: Design Processes  
Chair: Birkhofer, Herbert

## GENERIC MODEL OF THE EARLY PHASES OF AN INNOVATION PROCESS REGARDING DIFFERENT DEGREES OF PRODUCT NOVELTY

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Innovation processes are developed for various reasons, e.g. formalization, communication or controlling of development activities. There is a big variety of innovation processes and especially for its early phases to be found in literature directly correlating with the amount of different reasons for creating a new model. With the increasing number of models, the main benefit of formalization is obsolete: a comparative description how product design is carried out in a company. This papers deals with the early phases, the product planning and conceptual design of the innovation process. The literature lacks an overview of a generic model of the early phases. In order to deal with different degrees of product novelty, there need to be a flexible model in which a product planer is able to adjust his or her project of a new product flexibly depending on the determined degree of product revision. Therefore, the authors propose a merged model from a state of the art literature review with detailed income and outcome needed for each phase of the early planning process. It provides the opportunity to opt for three different degrees of product novelty.

## STRUCTURED CONCEPT DEVELOPMENT WITH PARAMETER ANALYSIS

**Kroll, Ehud**

*Technion-Israel Institute of Technology, Israel*

The popular systematic design process model prescribes functional decomposition and morphology as the main method for accomplishing the conceptual design phase. This approach exhibits some weaknesses, which are discussed and demonstrated with an example from a design textbook. It is shown that the method of functional decomposition and morphology requires the difficult task of creating a function structure, generates product concepts in a breadth-first manner that may also lack quantification, and most of all, does not offer a step by step mechanism for developing the concept, as opposed to just generating it. An alternative methodology, called parameter analysis, is proposed. It presents a more natural and efficient way of not only generating initial concepts, but also developing the concepts in a structured manner all the way to a viable conceptual design. The same example is used to show how parameter analysis focuses the designer's efforts on the most critical aspects of the evolving design and combines repeated cycles of conceptual level reasoning, configuration development with quantitative thinking, and critical but constructive evaluation.

## THE CONTINUOUS “FUZZY FRONT END” AS A PART OF THE INNOVATION PROCESS

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This work treats the method of creating and the importance of developing new product concepts as a basis for the future products development. Changes occurred in recent years have influenced shortening product's life cycle. Very intensive development of technology and market has significantly affected the process of new product development. Opportunities and ideas have become the main factors for the success of the new products. The basic criteria imposed in this process are to avoid mistakes by selecting weak concept that will engage significant product development resources and will not meet the expected market needs and expectation. Idea generation and evaluation should not be considered only in a Fuzzy Front-End of innovation process but in today's condition it is necessary to be considered as a separate, continuous process with the task of analysing the opportunities and ideas and creating a satisfactory number of concepts for the future products with good market potential. Some of the information presented is gathered during the research and participation in the process of creating new products.

## THE INFLUENCE OF A COMPANY'S STRATEGY ON CREATIVITY AND PROJECT RESULTS IN AN NPd – CASE STUDY

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There has yet been a lot of discussion on how important creativity is for the process of new product development. In the globalized competitive world of constant inflow of new consumer goods it is extremely important to establish a successful information network of knowledge sources (e.g. academia) and product producers (e.g. companies). The core of this network should become new product developers which are provided with real time flow of accurate and proper information. The developers could be company or academia placed, or either dispersed to some other locations. Since the developers strongly rely on the provided information, it is essential to establish the appropriate level of trust and support between all involved partners. In the year 2010 we had an opportunity to host at this course two companies concurrently, with two different development approaches. One company had a liberal view on a product development process and gave to the developers at the beginning only basic product constraints, while the other one set the product constraints much firmer. According to those constraints the teams took different approaches towards the new product development.

## AN EMPIRICAL EVALUATION OF A FRAMEWORK FOR DESIGN FOR VARIETY AND NOVELTY

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The objective of this paper is to empirically evaluate a framework for designing – GEMS of SAPPhIRE as req-sol – to check if it supports design for variety and novelty. A set of observational studies is designed where three teams of two designers each, solve three different design problems in the following order: without any support, using the framework, and using a combination of the framework and a catalogue. Results from the studies reveal that both variety and novelty of the concept space increases with the use of the framework or the framework and the catalogue. However, the number of concepts and the time taken by the designers decreases with the use of the framework and, the framework and the catalogue. Based on the results and the interview sessions with the designers, an interactive framework for designing to be supported on a computer is proposed as future work.

## WHEN SENSEMAKING MEETS RESOURCE ALLOCATION: AN EXPLORATORY STUDY OF AMBIGUOUS IDEAS IN PROJECT PORTFOLIO MANAGEMENT

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Research in Project Portfolio Management (PPM) has proposed tools and models for evaluating, selecting and prioritizing ideas and projects in product development. However, empirical evidence indicates that most companies still experience problems when managing their portfolios. PPM literature has mainly focused on evaluation models in which clearly defined ideas are evaluated against predetermined decision criteria. It is considered that this approach is not suitable for ambiguous ideas, where people face difficulties in understanding or classifying an idea. In this article we explore the evaluation of ambiguous ideas in PPM. We found that when people experience ambiguity they take small steps in the further development of an idea for giving to it the clarity that it was lacking before. This process for making sense of the ambiguous situation is conditioned by the resource allocation process which has its own logic and dynamic. We discuss these findings for explaining why some ideas are not evaluated according to the evaluation models proposed in PPM literature; and why the resource allocation process within PPM does not work as management planned it to.



# User Centered Design

Theme: Design Methods and Tools  
Chair: Farrugia, Philip

## A HAPTIC BASED HYBRID MOCK-UP FOR MECHANICAL PRODUCTS SUPPORTING HUMAN-CENTERED DESIGN

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The overall goal of the design process is to create products of good usability. A human-centered design process is characterized by a continuous involvement of the prospective user of the product. This also comprises user-based concept assessments and design optimizations. For this purpose in many cases it is necessary that the user is given the possibility to perceive the product emotionally. Thus the flexibility of digital mock-ups well established in digital engineering can't be used. Instead, physical prototypes are often indispensable. In this paper a \*\_Hybrid Mock-Up\_\* approach is presented that allows a physical interaction with virtual prototypes. The behavior of the product is simulated digitally whereas elements of the human-machine interface are emulated using a generic haptic device. The benefit of the approach is that for the user a realistic product perception is achieved without having to dispense with the advantages digital engineering offers: saving of costs and time due to a reduction of physical prototypes. The approach is illustrated in a case study of a crank driven car jack.

## CAN EXISTING USABILITY TECHNIQUES PREVENT TOMORROW'S USABILITY PROBLEMS?

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Product usability is necessary to ensure efficient and effective products which satisfy users. But despite all available usability techniques many users still experience usability problems when using electronic products. In this paper we present two studies that explore the (mis)match between types of uncertainty addressed by existing usability techniques and the types of uncertainty in the product development process that eventually can result in usability problems. For this research an uncertainty scale was developed, which is used in two studies. In the first study the uncertainty scale is used to relate usability techniques to the different types of uncertainty they address and in the second study to relate usability problems to different types of uncertainty. The overall contribution of this paper is that it offers greater insight into how usability techniques (do not) address uncertainty in the product development process.

## IDENTIFYING A DYNAMIC INTERACTION MODEL: A VIEW FROM THE DESIGNER-USER INTERACTIONS

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Design innovation research has discovered a variety of features, forms, and functions; however, the importance of the design process has not been studied adequately. Designers and users have been regarded as two primary stakeholders; yet, the interaction of designers and users has been neglected or separately highlighted in the literature on design process studies. Therefore, this study explores designer-user interaction in the process of design innovation. In order to address this, three interaction models are proposed (model of designers' interaction, model of users' interaction, and model of mutual interaction between designers and users). After these three presented interaction models, a designer-user interaction model can be synthesized as an outcome of this study. This model generates interactive paths between designers and users during a design project. In addition, the designer-user interaction model characterizes a design concept--design maturity in the process of design innovation.

## USABILITY COMPLIANT SUPPORTIVE TECHNOLOGIES IN SIMULATION-DRIVEN ENGINEERING

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One major characteristic of engineering procedure is the conduction of product development processes by efficient application of computer-aided tools (CAx-tools). But given that the development of those CAx-tools is mostly carried out by non-engineers, the systematic engineering practices are considered in a subordinated way. The current paper deals with a methodological approach to link theoretical simulation basics with practical program use special focusing on design-proximal simulation by finite element analysis (FEA). Examining the support functions (help documents, ...) of existing programs, their potentials are revealed. With the help of an implementation concept is demonstrated how modifications of the user interface, using tailored workflow schemes as well as modular handbooks can lead to major improvements in user support.

By a complete conceptual redesign of the supportive technologies, the user-program-interaction can be customized for engineering needs. The situation specific adaption of respective proceedings is dependent on the simulation type as well as the users' state of knowledge, which is to be shown in the second part of the essay.

# Cognition

Theme: Human Behaviour in Design  
Chair: Goldschmidt, Gabriela

## TAXONOMY OF COGNITIVE FUNCTIONS

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This paper presents a taxonomy of cognitive functions that supports formal functional modeling of cognitive technical systems (CTSs) and cognitive products. To date, there is little support for functional modeling of such systems and products even though their interdisciplinary complexity exceeds that of electro-mechanical products and makes modeling support in conceptual design even more important. The taxonomy of cognitive functions is based on literature research and consists of a set of cognitive capabilities on three hierarchical levels as well as a defined set of flows. Relationships among cognitive capabilities have been identified using WordNet, a lexical database of English. The application of the taxonomy is demonstrated through the example of a coffee robot waiter, which has been designed and prototyped in the research group of the authors. Through defining a common taxonomy of cognitive functions and flows, a common practice for functional modeling of cognitive products is defined thus supporting re-use of functional models. This creates the foundation for creating model-based design repositories for CTSs and cognitive products to support their future development.

## A NEW FRAMEWORK OF STUDYING THE COGNITIVE MODEL OF CREATIVE DESIGN

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University of New Brunswick, Canada

This paper proposes a new framework of studying the cognitive model of creative design. In this paper, first the general cognitive process of creativity is reviewed, and then current studies of the cognitive models in engineering design are introduced. Assuming design creativity is related with designer performance and design workload, a new framework is introduced to study factors affecting design creativity and designer's behavior in the cognitive process and the physical/physiological process. Experimental studies are proposed to validate the proposed framework and investigate the relation of design creativity with design performance and design creativity in the future work. This framework is expected to efficiently accommodate designer's role in the cognitive process and the physical / physiological process. The expected results of this framework will provide suggestions for promoting design creativity and develop an efficient design method to integrate designer's cognitive activities in the design process.

## DESIGNING: INSIGHTS FROM WEAVING THEORIES OF COGNITION AND DESIGN THEORIES

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This paper addresses the issue of 'What is designing?' from an unconventional perspective and aims to advance our understanding of what design really is. Designing has been studied from different perspectives but the underlying theoretical basis of studying the act has often been dispersed and not clear. To address these shortcomings the paper proposes a new topological structure that consists of two 3-dimensional spaces: Product-space and Social-space. The P-space is constructed by the complexity of the artifact, the number of disciplines involved and the availability of knowledge. The S-space consists of the number of disciplinary languages, number of different perspectives and the amount of openness and closeness of the social system that encapsulates the design activity. The two spaces are connected by means of theories on cognition, like: individual and distributed cognition, socio-linguistics, situated cognition, etc. Two examples serve to illustrate the proposed model and show that the act of designing involves the evolution of the artifact, social system, language and information embedded in the social and societal context.

## INITIAL CONDITIONS: THE STRUCTURE AND COMPOSITION OF EFFECTIVE DESIGN TEAMS

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Nearly all design work is collaborative work. The phenomenon of the multidisciplinary design team is increasingly common in both industry and project-based education. Existing research has shown that team diversity has mixed and often negative effects, especially when measured by demographic factors. However, relatively little research has been done on the cognitive style of team members, or "team cognitive diversity." Our research team is conducting a study examining several measures of cognitive style as they impact project performance for 15 collaborative student design teams. Though our full analysis is ongoing, a few noteworthy trends have emerged during our preliminary analysis. We believe that these trends, separate though they are from our central argument of cognitive diversity, have strong implications in understanding design teams and, ultimately, building teams for design success. In particular, trends relating to leadership, gender ratio and the peculiar influence of a cognitive factor called "Extraverted Feeling" will be discussed. We expand upon these findings and how they might be applied in multidisciplinary teamwork in design engineering education and practice.

# Cross-Domain Knowledge

Theme: Design Information and Knowledge  
Chair: Almekelt, Lars

## EXPLORING THE SYNTHESIS OF INFORMATION IN DESIGN PROCESSES – OPENING THE BLACK-BOX

Gumienny, Raja; Lindberg, Tilmann; Meinel, Christoph

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Information synthesis is an important part of design processes as it ensures to integrate, organize, filter, and evaluate essential information and constraints for the design solution. However, there are various methods, conditions and characteristics of synthesis and it is surprising that little research has focused on this subject yet. In this paper, we outline different approaches to information synthesis and report on our findings from interviews with designers in educational and corporate environments. From these findings we derive a framework in which we suggest to describe the characteristics of information synthesis via the chosen design paradigm as well as ten particular research perspectives. We regard this framework as a basis to understand information synthesis in greater detail and to show possible fields of future research. Additionally, it allows deriving insights how inexperienced designers as well as people from other domains who are involved in the design process can be supported.

## THE EVOLUTION OF INFORMATION WHILE BUILDING CROSS-DOMAIN MODELS OF A DESIGN: A VIDEO EXPERIMENT

Ahmad, Naveed; Wynn, David C; Clarkson, P John

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Building cross-domain models of the elements involved in design – such as requirements, functions, components and design activities can help generate and document design information. In this paper an evaluation is discussed, in which video experiments were used to explore the role of cross-domain modelling in information creation and evolution. The results of the experiments are discussed and some limitations of such evaluation methodology are highlighted.

## REPRESENTATION OF CROSS-DOMAIN DESIGN KNOWLEDGE THROUGH ONTOLOGY BASED FUNCTIONAL MODELS

Ovtcharova, Prof. Dr. Dr.-Ing. Jivka (1); Marinov, Milan (1); Gutu, Dan (1); Szots, Dr. Miklós (2); Simonyi, András (2)

1: Karlsruhe Institute of Technology, Germany; 2: Applied Logic Laboratory, Budapest, Hungary

Domain specific development environments such as MCAD/ECAD systems can partially exchange data based on standard data formats. Due to the complex interdependencies between mechatronical components and the diversity of the related product data, it is not possible to tackle the challenges of cross-domain engineering by means of direct information exchange only. An overarching information backbone, which can be understood by engineers and processed by computers is necessary.

This paper presents a function oriented, ontology based approach to provide such a backbone. A special functional structure models the functional interdependencies between mechatronical components. Two exemplary usages of the functional structure as information backbone are introduced: representation of interdependencies and reuse. A functional modeling ontology supports the creation, usage and maintenance of the functional structure. The ontology enables the definition of customizable taxonomies for functional modelling dialects and allows for semi-automatic reuse of product functions and mechatronical components.

## THE CHALLENGE OF HANDLING MATERIAL INFORMATION FROM DIFFERENT SOURCES

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1: BMW AG, Germany; 2: Chair of Engineering Design, University of Erlangen-Nürnberg

This article will analyze the challenge of handling material information from different sources and different phases in the development process of the automotive industry. The needs for various kinds of material information are analyzed by different subjects (legislative regulations, construction design, strategically requirements). The information sources are examined in order to understand the differences and the reasons for the difficulties that occur when integrating the material information into the systems and sources. As a result the main problem will be identified, which is the different semantics or naming of the materials.

Two possible solutions to overcome the difficulties and to make the available information accessible are evaluated and compared. These approaches are a data warehouse and an intelligent search engine. On the basis of the evaluation the search engine approach will be identified as the preferred one. While a more sufficient solution to solve the problem of the many sources is presented, this article also provides a solution to overcome the problem of the different semantics.

# Functional Reasoning I

Theme: Design Theory and Research Methodology  
Chair: Eckert, Claudia

## ACCEPTING AMBIGUITY OF ENGINEERING FUNCTIONAL DESCRIPTIONS

Vermaas, Pieter

Delft University of Technology, Netherlands, The

In this paper I consider four approaches to the ambiguity of engineering functional descriptions, and explore arguments for accepting this ambiguity. The first and second approach aim at resolving the ambiguity by finding or imposing a single precise meaning for function. These approaches lead to consensus on the content of functional descriptions and to their unconditional interoperability. Yet, these approaches counter the current engineering practice to use different meanings of function side-by-side. The third and fourth approach stay close to this engineering practice and accept the co-existing meanings of functions; in the third a single overarching meaning is still posited, and in the fourth function is taken as a Wittgensteinian family resemblance concept. It is described how having the co-existing meanings allows engineers to use different design methods. It is argued that the meaning of function then depends on the task for with functional descriptions are used. And it is proposed that functional descriptions have the methodological role in common to relate goal descriptions of devices with structural descriptions in a general and interdisciplinary way.

## A METHOD FOR SELECTING BASE FUNCTIONS FOR FUNCTION BLENDING IN ORDER TO DESIGN FUNCTIONS

Sakaguchi, Syo; Tsumaya, Akira; Yamamoto, Eiko; Taura, Toshiharu

kobe university, Japan

This study aims to develop a method for supporting the designs of new functions by extending the conventional design processes in conceptual design. By focusing on concept blending that can create new concepts, we have developed a method of function blending in the design process. However, the selection of the functions (base functions) to be blended still remained an unsolved problem. In this paper, we propose a method for selecting base functions to design new functions. Design is often considered to be a problem-solving process. Our method for selecting the base functions has been developed by analysing the nature of the problem-solving process. In particular, we have addressed the antonymic relations between the verbs in the base functions, which play important roles.

## DESIGN OF FUNCTIONS BY FUNCTION BLENDING

Park, Yu; Ohashi, Shota; Yamamoto, Eiko; Taura, Toshiharu

Kobe University, Japan

This study aims to develop a method for supporting the design of a new function. Currently, in product development and design, the question “What should we create?” is the main issue to be addressed, whereas, previously, the main issue was “How should we realize the given function?” In this study, we approach the current issue by designing a new function. We propose the method of “function blending” to support the design of a new function structure. This method is systematized from a linguistic viewpoint so that a new function structure can be derived using linguistic hierarchical relations. We develop the formulation of function blending in a function dividing process, and a method for developing a thesaurus for function blending. Finally, we confirm the feasibility of the proposed method.



## TOWARDS A SCIENTIFIC MODEL OF FUNCTION-BEHAVIOR TRANSFORMATION

Chen, Yong; Zhang, Zhinan; Liu, Zelin; Xie, Youbai

Shanghai Jiaotong University, China, Peoples Republic of

The function-behavior transformation, though widely acknowledged as a significant process of engineering design, is still regarded as a subjective and experienced-based process. This paper is therefore devoted to proposing a logical and scientific model for this transformation process for building a science of designing. It clarifies the concepts of function, behavior and structure in designing, with some significant features of them identified. Especially, the subject-object relationship in philosophy is employed to clarify the above related concepts. Existing understandings about these concepts are also analyzed for comparison. A new concept, physical action, is elaborated and introduced into design science. A scientific function-behavior transformation model, called the Function-physical Action-Behavior (abbreviated as FAB) model, is then proposed, where the concept of physical action is successfully used to bridge the gap between function and behavior. An illustrative example is provided to demonstrate the proposed FAB model.

	Discussion Sessions			Podium Sessions			Workshop Sessions		
08:30 - 10:00	Innovation and Creativity Support Room: Discussion Room 1 Theme: Design Methods and Tools p58			Design Theory Proposals Room: Podium Room s01 Theme: Theory and Research Methodology p64			EcoDesign SIG Workshop: Eco-optimised LEGO Power Functions Room: Workshop Room s08 p55		
10:00 - 10:30	Break			Search and Knowledge Discovery Room: Podium Room s09 Theme: Design Methods and Tools p65			Mechatronics SIG Workshop: Engineering Design in Mechatronics Room: Workshop Room s16 p56		
10:30 - 11:50	Creativity Room: Discussion Room 1 Theme: Human Behaviour in Design p68	Clearing the Road for Innovation Room: Discussion Room 2 Theme: Design Organisation & Management p60	Technical Applications of Design Room: Discussion Room 5 Theme: Product and Systems Design p62	Deploying Business Strategy in NPD Room: Podium Room s01 Theme: Design Organisation & Management p74	Knowledge and Industry Room: Podium Room s09 Theme: Design Information and Knowledge p75	Tools and Methods for Producing Form Room: Podium Room s02-03 Theme: Design Information and Knowledge p66	Inspiration Room: Podium Room s10-11 Theme: Human Behaviour in Design p67	Risk Management SIG Workshop: Processes and Methods in Design Room: Workshop Room s06 p57	
12:00 - 12:30	Aerospace Keynote: Designing a Spaceship for Everyone! Jonathan Firth, Virgin Galactic Main Hall						p78		
12:30 - 13:00	Innovation Keynote: The Future of Innovation Bettina von Stamm, Innovation Leadership Forum Main Hall						p79		
13:00 - 14:15	Lunch			Lunchtime Tutorial: Writing, Reviewing and Publishing Scientific Papers in Design Room: Glass Room			p80		
14:15 - 15:45	Research Methods for Studying Designers Room: Discussion Room 1 Theme: Theory and Research Methodology p84	From Requirements to Embodiments Room: Discussion Room 2 Theme: Design Methods and Tools p86	Medical Devices and Related Applications Room: Discussion Room 5 Theme: Product and Systems Design p88	Eliciting Customer and Stakeholder Requirements Room: Podium Room s01 Theme: Design Methods and Tools p90	Evaluation Techniques Room: Podium Room s09 Theme: Human Behaviour in Design p91	Mechatronics Design Room: Podium Room s02-03 Theme: Design Processes p92	Design Curricula Room: Podium Room s10-11 Theme: Design Education p93	MMEP SIG Workshop: Current Research and Future Directions Room: Workshop Room s08 p82	
15:45 - 16:15	Break						Design Theory SIG Workshop: Advancement and convergences Room: Workshop Room s16 p83		
16:15 - 17:45	Design Process Improvement Room: Discussion Room 1 Theme: Design Processes p94	Emotion Room: Discussion Room 2 Theme: Human Behaviour in Design p96	Capturing Value Room: Discussion Room 5 Theme: Design Methods and Tools p98	Function and Performance Modelling Room: Podium Room s01 Theme: Design Methods and Tools p100	Design for Modularity Room: Podium Room s09 Theme: Design for X, Design to X p101	Functional Reasoning II Room: Podium Room s02-03 Theme: Theory and Research Methodology p102	Structuring Information and Knowledge Modules Room: Podium Room s10-11 Theme: Design Information and Knowledge p103	Dansk Industri Industry Workshop (separate invitation required) Room: Oticon	
18:30 - 20:00	Welcome Reception City Hall						p17		

ECODESIGN IMPLEMENTATION: ECO-OPTIMISED LEGO POWER FUNCTIONS

Chairs: Niki Bey (DTU) and Tim McAloone (DTU) in collaboration with LEGO System A/S

The Ecodesign SIG has teamed up this year with LEGO System A/S, where the object of our workshop will be LEGO's Power Functions product. As always, the aim of the workshop will be to discuss our various tools and theoretical models on one common case product.

LEGO's motivation

LEGO has been working for some years with continued environmental improvement of their products, through the integration of environmental thinking into the product development process. They are aware of many of the tools and techniques available, and are on a constant search for best practice. The choice of case product for this workshop reflects LEGO's challenge in designing environmentally optimised electrical/ electronic products, including all of the other aspects (materials choice and design for disassembly/recycling, etc.) that go with any product design process. For the Power Functions product particularly interesting focus areas include disassembly/recyclability; reduction of materials; simplification of components; exciting alternative eco-materials and energy efficiency in operations. The outside measurements of the components are fixed to fit with the LEGO system and cannot be challenged.

The research community's motivation

As engineering design and product development researchers we are actively creating theories, models and methods for product improvement. Many of us are also engaged in the specific area of ecodesign. For the rest of the ICED conference we will discuss research results and intentions, and we will debate about best practice, rigorous methodologies. This workshop is an opportunity for us to break out and try out our methods in collaboration with a real-life company, on a real-life product!

Taking a common product from the LEGO group, we can reach a very rich dialogue about our own ecodesign methods and models, whilst at the same time creating a set of concepts together with the company. We will round up the workshop with a discussion of ecodesign implementation in industry.

Workshop programme

08:30 - Welcome introduction and game-rules

08:45 - Short presentation by LEGO

- Eco-design focus areas and activities
- Hopes and wishes for today's workshop

09:00 - 5-8 short presentations of ecodesign concepts (from active delegates)

- Implementation of own methods
- Ideation based on own theories
- Comparisons of two LCA tools

09:50 - Group formation and ecodesign activities start (including coffee-to-go)

10:30 - Group work continues (delegates choose a group, according to the intro presentations)

- Discussion of proposed concepts
- Ideation
- Discussion of utilised methodologies
- Creation of an idea eco-concept for LEGO Power Functions

11:15 - Report back and discussion

- of concepts produced and eco-proposals derived
- of methods used for this exercise
- of an implementation strategy for LEGO

11:50 - Close





ENGINEERING DESIGN IN MECHATRONICS

Chair: Stefan Moehringer (Simon Moehringer Anlagenbau)

About the workshop

Mechatronics - the synergetic integration of different engineering domains such as mechanics, electronics and information technology can create new products and stimulate innovative solutions. In spite of the attractiveness of Mechatronics, mechatronic-specific design aspects are rarely considered in research.

Based on the findings of SIG workshop 2010 in Dubrovnic this workshop intends to bring forward the idea of a research framework for design in mechatronics (Möhringer/Stetter, 2010).

Agenda

The focus of interest is mainly:

- How to support multidisciplinary in mechatronic-specific design,
- How to implement new product development processes for a cross-domain approach,
- How to increase visibility of design results and design changes during this process,
- How to handle complexity in mechatronic design,
- How to position design approaches between evolutionary and revolutionary design.

At the occasion of SIG workshop 2010 a survey among the participants has been made in order to classify the type of research which is done within the design community. The results of this survey will be presented by the chair.

Selected presentations (4 or 5) from experts in the field of mechatronics will give initial information on the mentioned topics. Following these presentations an intensive discussion is expected.

Based on the survey the next strategic question for the SIG will be: how can design proceeding in mechatronic design be described in a more detailed way? Stetter, Möhringer and Pulm suggest two main design proceedings: evolutionary and revolutionary design. Examples from with different industrial context (automotive and plant engineering) are given. A discussion regarding these design types will be moderated.

The workshop wants to bring together people who work in the field of mechatronic-specific design science and provide them with a forum to present and discuss their ideas.

KICK-OFF MEETING OF THE SIG ON “RISK MANAGEMENT”  
PROCESSES AND METHODS IN DESIGN

Chairs: Josef Oehmen (MIT) and Warren Seering (MIT)

About the Risk Management SIG and the Workshop

The objective of the newly founded Risk SIG is to take a fresh look at product design through the lens of risk management.

Both product development activities as well as risk management activities aim at reducing uncertainty. In a nutshell, our idea is that both disciplines can benefit from an exchange of ideas and concepts. Also, risk management play an important role as a sub-process in product design. With the release of the ISO 31000 risk management norm, the relationship of product design and risk management can be re-examined, both in terms of defining advanced risk management processes for design, as well as integrating risk management as an intrinsic part into design.

We propose to take a fresh look at design processes through the lens of risk management. We believe that risk management has passed a critical maturity level. We make the case that the Design Society not only participates in, but also defines the cutting edge of research by building a community to explore and define a research agenda on Product Design Risk Management (PDRM).

- Our current goals for a three year period, subject to discussion at the workshop, are:
- Map out current research activities in the field and define future research agenda
- Build a networking platform for researchers interested in risk management in design
- Publish a special issue on risk management in design
- Publish an edited book summarizing the current state of knowledge in design risk management

Agenda

- Welcome and introduction
- Introduction of participants and their research interests
- In parallel: Collection of research interests on pin board
- Discussion and networking in groups (per research field) to explore opportunities for collaboration (e.g. joint publications)
- Discussion of SIG goals and finalization of 3 year plan
- Draft outline of call for papers for special issue on design risk management (based on research fields)
- Discussion of possible journals
- Discussion of possible co-editors and of involvement of SIG in review process
- Planning of future interaction and meeting

# Innovation and Creativity Support

Theme: Design Methods and Tools  
Chair: Lenau, Torben

## INNOVATION THROUGH DESIGN FOR EMOTION

**Guenand, Anne; Berdillon, Vincent**

*University of Technology of Compiegne, France*

Innovation represents a key role in firm success. Though the literature provides much advices and methods, companies sometimes do not know how to proceed when they feel they have exhausted all innovation possibilities or when they are in need of a specific type of evolution. The present paper proposes an overview of product innovation types and emotional design methods to make competitive products, bringing emotional benefits to the final users. Based on the synthesis of existing methods and tools from the literature and on our experience in design for emotion, we propose to illustrate how to design for emotion in the three main types of product innovation: incremental, disruptive and forecasting. We propose a visual tool, a brochure, dedicated to SMEs, to help understanding the differences between these types of innovation and how design for emotion can contribute to each type of innovation. Each case is supplemented with a toolbox of relevant tools, allowing company’s design team to understand and to start innovation through design for emotion.

## IMMERSIVE PRODUCT IMPROVEMENT IPI – FIRST EMPIRICAL RESULTS OF A NEW METHOD

**Kirschner, Rafael (1); Kain, Andreas (1); Lang, Alexander (2); Lindemann, Udo (1)**

*1: TU Munich, Germany; 2: Iman solutions GmbH, Germany*

Despite the widely accepted and proven benefits of open innovation methods, companies apply them infrequently in their own product development processes. In order to find reasons for this apparently contradiction, we conducted 34 interviews with project directors and a literature study. Thus, we identified ten common obstacles for customer integration. On this basis, we derived a new open innovation method to get over these hurdles. The core idea of the presented crowd sourcing method is a product picture based access to a suggestion management database by the product user. To illuminate the method, we present an implementation together with its internal data structure for a better understanding. This tool is then validated in an experiment with n=48 users of a telephone. The results indicate that the picture based approach of the method generates better results than a conventinal list based approach.

## APPLICATION OF BASIC DESIGN PRINCIPLES FOR SOLUTION SEARCH IN BIOMIMETICS

**Parvan, Manuela Iulia; Schwalmberger, Andreas; Lindemann, Udo**

*Institute of Product Development TU München, Germany*

The main purpose of biomimetics lies in solving technical problems by searching solutions in the vast field of biology and transferring these into technical products. This approach leads to a high degree of innovation that is often needed in critical design situations. The process of finding adequate solutions in biomimetics is very difficult to pursue. Problems lie in the difficult communication between engineers and biologists and the mutual understanding of these two disciplines due to differences in terminology and design processes. In this paper a method of improving the solution search process in biomimetics by using basic design principles is presented. From existing design principles in biology and engineering, biomimetic principles are derived. With the aid of specific generated principles engineers and biologists can conduct the search for solutions more simple and effective. The biomimetic principles are embedded in an application process. Hence, the user in case is conducted through the searching process systematically. The application of basic principles helps engineers and biologists to understand each other without the need of being experts in both domains.

## COLLABORATIVE IDEA GENERATION USING DESIGN HEURISTICS

**Yilmaz, Seda (1); Christian, James L. (2); Daly, Shanna R. (2); Seifert, Colleen M. (2); Gonzalez, Richard (2)**

*1: Iowa State University, United States of America; 2: University of Michigan, United States of America*

Creative strategies play a central role in successful concept generation; however, few studies have documented the application of creative strategies in engineering design. From protocol studies of engineering and industrial designers, heuristics, or cognitive shortcuts, were identified that support novel and diverse concept generation [1]. In this study, professional engineers from a manufacturing company participated in a small group innovation workshop using the developed “Design Heuristics.” The team was videotaped as they worked with the instructional cards we developed based on the heuristics. This paper reports on the investigation of the design team’s idea generation process with five of the cards, analyzing the diversity of their ideas, how Design Heuristics were used, and their role in stimulating both new design solutions and problems. The introduction of a specific design heuristic often guided designers to a different part of the design space, and facilitated them in considering other unprompted heuristics.

## BIOINSPIRED CONCEPTUAL DESIGN (BICD): CONCEPTUAL DESIGN OF A GRASSHOPPER-LIKE JUMPING MECHANISM AS A CASE STUDY

**Konez Eroğlu, Aylin; Erden, Zühal; Erden, Abdulkadir**

*ATILIM University, Department of Mechatronics Engineering,Turkey*

The evolution process of nature creates \_highly effective, power efficient,\_ and \_perfectly structured\_ biological systems. These excellent systems provide an inexhaustible source for engineers and scientists who desire to inspire ideas, processes, structures, functions, and behaviors from biological domain and implement them into engineering domain. This approach is called “Bioinspired” and challenging for engineers. However, some problems of the practical approaches are observed. One of the problems is “ad hoc” nature of the process. Each bioinspired design product has resulted in a differing design process and a generalization was not possible. Another problem rises due to the terminology difference between engineers and biologists. To overcome these problems, a need for a systematic \_bioinspired design\_ (BID) process was realized in early 2000s and since then, considerable research on the BID methodology has been progressed. Within the context of BID, this paper introduces a new approach on bioinspired conceptual design (BICD) procedure for hybrid bioinspired robots which can be inspired from multiple biological systems. An illustrative case study is given in the paper.

# Clearing the Road for Innovation

Theme: Design Organisation and Management  
Chair: Norell Bergendahl, Margareta E B.

## EXPLOIT AND EXPLORE: TWO WAYS OF CATEGORIZING INNOVATION PROJECTS

**Ericson, Åsa; Kastensson, Åsa**

*Luleå University of Technology, Sweden*

Innovation is vital to companies, but also difficult to perform since there are many ways to approach the subject. Typically, a balance between all issues related to innovation is suggested in literature. The empirical study presented in this paper elaborates on two strategies for innovation projects, namely to exploit existing solutions and to explore a market to develop breakthrough solutions. This is done for the purpose to discuss management implications, and thereby also make those transparent for innovation projects. The result indicates that managerial implications for radical innovation projects are to provide internal legitimacy for the projects intentions, to provide for a clear view of balancing aspects by using concepts that fit into opposite ends on a continuum, and to preserve a rich information base about users.

## EXPERIENCES WITH IDEA PROMOTING INITIATIVES - WHY THEY DON'T ALWAYS WORK

**Gish, Liv**

*Technical University of Denmark, Denmark*

In new product development a central activity is to provide new ideas. Over the last decades experiences with stimulating employee creativity and establishing idea promoting initiatives have been made in industrial practice. Such initiatives are often labeled Idea Management – a research field with a growing interest. In this paper I examine three different idea promoting initiatives carried out in Grundfos, a leading pump manufacturer. In the analysis I address what understandings of idea work are inscribed in the initiatives and what role these initiatives play in the organization with respect to idea work. Furthermore I look into what makes these initiatives ‘work’ or ‘not work’. The analysis builds on an in-depth case study made in Grundfos based on 40 interviews with R&D professionals and managers. The managerial implications of the study are that managers should be aware of what understandings of idea work are inscribed in the idea promoting initiatives as they to some degree have to fit with the understandings embedded in practice in order to work.

## TECHNOLOGY DEVELOPMENT PRACTICES IN INDUSTRY

**Högman, Ulf; Johannesson, Hans**

*Chalmers University of Technology, Sweden*

This article concerns technology development practices in industry. Its primary foci are on describing the technology development process, its management through normative models, and how technology is integrated and exploited through different platform approaches. The aim of the study has been to explore the external validity of previously acquired empirical results which have been obtained through a series of studies in Volvo AB, and in particular in the company context of Volvo Aero Corporation (VAC).

In order to meet our aim we have chosen a multiple case study approach, involving four different companies. Obtained results have been compared in between the different cases and reflections have been made relative to what has been reported from earlier studies at Volvo Aero Corporation, and thereby indirectly to what can be found in literature.

What we can conclude is that most of the results previously obtained in VAC have also been found in the four companies included in this study. Apart from giving this answer to our research question, this article contributes with empirical results from five different contextual settings concerning some aspects of technology development.

## ENGINEERING ENVIRONMENT FOR PRODUCT INNOVATION

**Bitzer, Michael (1); Vielhaber, Michael (2)**

*1: Accenture, Germany; 2: Saarland University, Germany*

Product innovations and the competence to innovate are key success factors for any industrial enterprise. When looking inside product development departments, time, cost and quality are generally the predominant goals, which are then targeted by the engineering environment comprised of organizational measures, business processes, methods, and supporting IT systems. Innovation seems to be left the role of an appreciated side-effect. This paper investigates how an engineering environment should be designed in order to foster innovation. What should – against this background – be the interplay between processes, methods and IT?

Product Lifecycle Management (PLM) is a concept often promoted for product development to address both time/cost/quality and innovation. This paper gives advice on how PLM is to be understood and set up to achieve this with best possible results.

## HOW DESIGN RESEARCHERS CAN LEAD HIGHER EDUCATION TO A GREATER IMPACT ON SOCIETY

**Howard, Thomas James; McMahon, Christopher A; Giess, Matthew David**

*Technical University of Denmark*

This paper argues for the lead rôle that the engineering design research community can have in aiding SMEs. The paper details findings based on several rounds of calls and meetings with a total of over 600 SMEs, and interviews with members of large design and manufacturing research group. It was found that SMEs mainly requested support with specific product related problems and tasks, rather than improvements to process or practice. It was also found that university faculty members have little time or incentive to provide such support which may not directly progress a research portfolio. However, with the aid of available government funding, researchers could benefit from undertaking such support work to fill gaps between fixed term research contracts; though administering short term irregular contracts proved a major unresolved barrier. It is recommended that engineering design researchers work as projects managers to provide technology and knowledge transfer, drawing further expertise from researchers within their universities. A trail case was completed showing identifying three key barriers to future progress.

## STAKEHOLDERS’ ANALYSIS TOOLS TO SUPPORT THE OPEN INNOVATION PROCESS MANAGEMENT – CASE STUDY

**de Paula, Istefani Carisio; Yang, Samanta; Korzenowski, André; Cortimiglia, Marcelo Nogueira**

*Rio Grande do Sul Federal University, Brazil*

Open Innovation (OI) is a strategy to buster R&D productivity that introduces business flexibility via an open approach, either to external ideas or to collaborative work. Considering that the OI concept changes the perception of value creation and raises the number of stakeholders that contribute to a single project, stakeholders’ analysis seems to be adequate to identify the network partners involved in a project for management purposes. The aim in this paper is to propose a set of tools for stakeholders’ analysis, directed to the identification, prioritization and categorization of stakeholders in an OI management environment. The tools were tested, based on a qualitative approach, in a case study in the Brazilian Pharmaceutical industry. The study led to the understanding of the relationship’s importance and correlation of stakeholders in four representative pharmaceutical organizations that adhered to the OI strategy. The set of tools were useful to access the incoherence between the importance attributed to a given stakeholder and the kind of collaboration he shares. It revealed that the intensity of the relationships between them is different from a company to another.



MODELING AND DESIGN OF CONTACTS IN ELECTRICAL CONNECTORS

**Albers, Albert; Martin, Paul; Lorentz, Benoit**  
*Karlsruher Institute of Technology (KIT), Germany*

The presented paper focuses on modeling and simulation of electrical connector contacts’ behavior and associated design. New solutions are developed, based on the Contact & Channel Approach validated by simulation and experiment. Primary parameters such as contact resistance, tribological and thermal behavior, contact force, material and connector size strongly influence electrical connector’s properties. Therefore, a great deal of experience or effort is needed to design application specific solutions mastering preceding interrelated parameters. However, many state of the art electrical connectors are, especially for high currents, designed by trial and error processes. In order to increase efficiency and effectiveness of the design process, appropriate models are needed. To generate new design solutions, models of a certain level of abstraction are needed. In addition to this, holistic computer-aided models enable the prediction of connector’s electrical and mechanical performance. Here, design solutions are created based on the Contact & Channel Approach. At the same time a Finite Element Model is built in order to investigate the behavior of designed connector’s prototypes.

ACTUATION PRINCIPLE SELECTION – AN EXAMPLE FOR TRADE-OFF ASSESSMENT BY CPM-APPROACH

**Erbe, Torsten (1); Weber, Christian (1); Paetzold, Kristin (2)**  
*1: Ilmenau University of Technology, Germany; 2: Universität der Bundeswehr München*

The generation of motion is a task of many technical systems. Customized drive systems formulate the challenge of the selection of a suitable actuator during the development of drive systems. Common approaches and tools for actuator selection are limited to the selection of known actuators out of a database. However, especially at the cutting edge of technology conflicts of requirements complicate the selection of a suitable actuator or even actuation principle. This paper uses the CPM / PDD approach to describe a concept of visualizing the properties and characteristics of actuator-principles in order to identify potential for influence by the designer. Based on the context precision engineering, measures to meet conflicting objectives and to identify convenient characteristics for adaption as well as limitations of the proposed approach are discussed.

ENHANCING INTERMODAL FREIGHT TRANSPORT BY MEANS OF AN INNOVATIVE LOADING UNIT

**Klingender, Max; Jursch, Sebastian**  
*IMA/ZLW & IfU - RWTH Aachen University, Germany*

Aim of the project “TelliBox - Intelligent MegaSwapBoxes for advanced intermodal freight transport” has been to develop and prototype a new intermodal loading unit by an international consortium. This new 45 feet long intermodal loading unit is applicable to be transported on road, rail, short sea and inland waterways. It combines the advantages of currently available loading units, e.g. flexibility and safety of containers, loading facilities and internal cargo dimensions of semitrailers and the effective use of loading areas of swap-bodies, in one sustainable loading unit solution. The efficient and successful usage of this new solution has been also verified on a demonstration trial within an European automotive industry transport corridor.

LINEAR FLOW-SPLIT LINEAR GUIDES: INFLATING CHAMBERS TO GENERATE BREAKING FORCE

**Lommatzsch, Nils; Gramlich, Sebastian; Birkhofer, Herbert; Bohn, Andrea**  
*TU Darmstadt, Germany*

The linear flow-splitting technology developed within the Collaborative Research Center (CRC 666) “Integral Sheet Metal Design with Higher Order Bifurcations” offers new options to manufacture innovative products. Especially using the technology to continuously produce linear guides is focused in this research. With linear flow-splitting and linear bend-splitting, chambered steel profiles provide possibilities to integrate functions into linear guides. In this contribution, an approach to develop functions for linear flow-split linear guides is presented. Basing on calculation models and property networks, optimized solutions can be created while design modifications can be derived from the property networks. These property networks are very well suited to present an easy overview over the so called “set screws” with which the fulfillment of the requirements can be influenced. The approach also includes the validation of the calculation models and the functionality with finite element models and experiments. The approach is explained on the example of the function “clamping”.

EVALUATION OF AN AUTOMATED DESIGN AND OPTIMIZATION FRAMEWORK FOR MODULAR ROBOTS USING A PHYSICAL PROTOTYPE

**Nezhadali, Vaheed; Kayani, Omer Khaleeq; Razzaq, Hannan; Tarkian, Mehdi**  
*Linköping University, Sweden*

This paper presents an automated design and evaluation framework, by integrating design tools from various engineering domains for rapid evaluation of design alternatives. The presented framework enables engineers to perform simulation based optimizations. As a proof of concept a seven degree of freedom modular robot is designed and optimized using the automated framework. The designed robot is then manufactured to evaluate the framework using preliminary tests.

AUTOMATED USER BEHAVIOR MONITORING SYSTEM FOR DYNAMIC WORK ENVIRONMENTS

**Choi, Yeeun; Jang, Misun; Kim, Yong Se; Lee, Seongil**  
*Syungkyunkwan University, Korea, South (Republic of)*

This study's aim is to improve existing methodology for users’ evaluation that performs tasks in environment observation. We examine a new user's monitoring system and analyze for monitoring users’ behavior in more complex and dynamic work environments with more than one user. Making more possibilities using by quantitative ways, we also perform object tracking using RFID and four video cameras. We designed smart floor monitoring system tracking user's movement through variation of pressure sensors. The system is installed in an observation room in where is simulated a take-out coffee shop for verification the utility of the proposed new monitoring system for this study. After analyzing data of monitoring users’ behavior, we analyze correlation referring to the users from user's movements and action.

VIRTUALISATION OF PRODUCT DEVELOPMENT/ DESIGN – SEEN FROM DESIGN THEORY AND METHODOLOGY

Weber, Christian; Husung, Stephan

Ilmenau University of Technology, Germany

Over the last decade terms like “Virtual Prototyping”, “Virtual Engineering”, “Virtual Product Development” and “Virtual Reality” have been propagated. These terms mostly come from other disciplines and stakeholders (e.g. from developers of computer tools, computer science in general), their use still is somewhat messy. This paper tries to define a base for these issues from the perspective of Design Theory and Methodology which should be the base discipline for investigating, systemising and improving product development/design processes, but has not yet come to a decisive viewpoint about the implications and use of the terms mentioned.

ENVIRONMENT BASED DESIGN (EBD) VS. X DEVELOPMENT: A DIALOG BETWEEN THEORY AND RESTROSPECTION

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1: Concordia University, Canada; 2: Université de Bretagne Occidentale

This paper presents two independently developed design methodologies: Environment-Based Design (EBD) and X-Development. These two methodologies share exactly the same foundation: design is based on environment. The environment is where the designed product is to work. The environment was there, is there, and will still be there. Any design action changes only the environment. This paper thus conducted a preliminary comparison of these two methodologies. This coincidental convergence of two design methodologies provides one kind of support to the each other. Future work will be focused on the formalization and refinement of X-Development through the mathematical operations included in the EBD.



THE SEMANTIC DEBATE IN DESIGN THEORIES APPLIED TO PRODUCT IDENTITY CREATION

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NTNU - Norwegian University of Science and Technology, Norway

The process of form giving is a complex topic for product designers and is inherently connected to the field of aesthetics. Fundamental questions need answers. Are there absolute aesthetic principles that, if followed, can guarantee a “good form” and a successful product? What importance should user and market response be given? This highlights the debate on the extent to which the designer is entitled to be the only judge of a product’s aesthetics, as well as on how much other stakeholders (such as client companies, product users) have a say in the product’s meaning creation through its form.

In the past century the modernist paradigm and its translation in functionalist principles for product design has prevailed. However this paradigm has been increasingly challenged in the beginning of this century with the emergence of human-centered design theories.

This article attempts to give an overview of how this paradigm shift from positivist to constructivist philosophical worldviews has impacted design theories and form-giving principles. The purpose is to give young designers a basis for reflection on aesthetics and the creation of meaning and identity through form giving.



A SYSTEMATIC APPROACH OF DESIGN THEORIES USING GENERATIVENESS AND ROBUSTNESS

Hatchuel, Armand (1); Le Masson, Pascal (1); Reich, Yoram (2); Weil, Benoit (1)

1: Mines ParisTech, France; 2: Tel Aviv University, Israel

In this paper we build a systematic comparison of several formal design theories: General Design Theory, Axiomatic Design, Coupled Design Process, Infused Design and C-K theory. Each theory offers principles as well as mathematical assumptions and establishes propositions that we analyze through two main criteria: i) their generativeness, i.e. their ability to produce design proposals that are different from existing solutions and design standards; ii) their robustness, i.e. their ability to produce designs that resist variations of context. Using such framework, and focusing on the evolution of the mathematical assumptions of each theory, it can be shown that the development of design theories does not reflect radically different point of views about design. Instead, there is an evolution towards more generality and less dependency on predefined objects. They form altogether a consistent body of knowledge that has aimed to increase the generativeness of design without losing its robustness. Thus, Design science can be seen as the science of “generativity”. The evolution of design theories is illustrated by applying each of them to the same brief: the design of a new camping chair.

SCENARIO-BASED DESIGN IN DESIGN PATTERN MINING

Iacob, Claudia

University of Milan, Italy

Design patterns are tools to support social creativity in that they allow communities of designers to make available knowledge related to design experiences, such as problems, solutions and design decisions. Identifying design patterns is a process known as design pattern mining. This paper describes one of the techniques used throughout a series of design workshops held for identifying design patterns in the design of software applications for synchronous collaboration. The paper describes the way the technique was applied in concrete design cases, and its influence on the results obtained throughout the workshops. Results indicate that the use of scenario-base design supports the exploration of the design space of the application under design. This allows the generation of a larger number of scenario ideas to support the design pattern mining process.

PREDICTING EMERGING PRODUCT DESIGN TREND BY MINING PUBLICLY AVAILABLE CUSTOMER REVIEW DATA

Tucker, Conrad; Kim, Harrison

University of Illinois at Urbana-Champaign, United States of America

In this work, the authors present a robust framework to enrich new product design process by dynamically capturing customer preference trends. The framework autonomously captures customer preference trends from publicly available product review data which is abundantly available but grossly underutilized. The method overcomes a major challenge that has plagued the product design community – the lack of large scale, realistic customer data and its meaningful interpretation to guide new product design process. The challenge is from conventional, prevalent use of customer surveys or focus group interviews that are usually costly and time consuming while the size of available data is usually small scale. The framework is composed of three steps – retrieval of customer review texts, mining product feature texts, and predicting future trend of product preference.

A METHODOLOGY FOR DISCOVERING STRUCTURE IN DESIGN DATABASES

Fu, Katherine; Cagan, Jonathan; Kotovsky, Kenneth

Carnegie Mellon University, United States of America

Design by analogy, in which designers draw inspiration from cross-domain design solutions, is a promising methodology for product development. This work attempts to leverage the existing design solutions within a repository, combined with an exploration of inherent structural forms that can be discovered based on the content and similarity of that data, in order to gain useful insights into the nature of the design space. In this work, the approach will be applied to uncover structure in the U.S. patent database. Methodology for generating and analyzing these structures is presented here, in addition to insights from some initial results. These insights could generate fodder for stimulating design inspiration and innovation for engineering designers.

SEARCH FOR SIMILAR TECHNICAL SOLUTIONS BY OBJECT ABSTRACTION USING AN ONTOLOGY

Kohn, Andreas; Lindemann, Udo

Technische Universität München, Germany

The search for existing solutions in mechanical engineering is a key-factor for successful product development. By reusing existing solutions, the amount of work and costs within the product development process can be reduced. However, not only exact matches for a required solution are helpful, but also the suggestion of similar solutions could often meet the requirements and bring benefit. Therefore, the presented research aims at improving the process of retrieving existing solutions similar to a user query. This is achieved by developing an abstraction level in form of a shape classification for the objects handled in a technical solution. An ontology is used for modeling the required concepts and providing the necessary relations to shape classification. Semantic similarity measures are applied for calculating the similarity of technical solutions and the user query according to the information modeled in the ontology. With the help of a developed prototype that uses the ontology as knowledge repository for annotating and searching solution documents, the presented approach is applied and evaluated in the field of automation industry.

# Tools and Methods for Producing Form

Theme: Design Methods and Tools  
Chair: Mullineux, Glen



## UNDERSTANDING STYLING ACTIVITY OF AUTOMOTIVE DESIGNERS: A STUDY OF MANUAL INTERPOLATIVE MORPHING THROUGH FREEHAND SKETCHING

**Zainal Abidin, Shahrman Bin (1,3); Warell, Anders (2); Liem, Andre (3)**

1: Universiti Teknologi MARA, Malaysia; 2: Lund University, Sweden; 3: Norwegian University of Science and Technology, Norway

Automated morphing techniques have been proposed as a design support tool to generate novel shapes which lie between two or more polar reference images. The purpose of these techniques, employed in automated morphing systems (AMS), is to assist designers and design teams in the task of generating new shapes and finding novel form concepts. In this paper, we investigate the sketching processes of automotive designers in order to understand their processes of manual interpolative morphing employing freehand sketching. Results suggest that there are profound differences between manual and automated morphing. Specifically, these relate to selectivity, consistency, and completeness of morphing operations. While designers choose and transform shape based on subjective and purposeful intent, AMS lack these characteristics. These differences influence the outcome of morphing processes to a fundamental degree. The research describes the characteristics and clarifies the potential contribution of AMS in styling activities, thus assisting the evaluation of AMS in relation to traditional, manual sketching approaches.

## A KNOWLEDGE-BASED SUPERPOSING SKETCH TOOL FOR DESIGN CONCEPT GENERATION THROUGH REFLECTION OF VERBAL AND DRAWING EXPRESSION

**Nomaguchi, Yutaka; Kotera, Yuko; Fujita, Kikuo**

Osaka University, Japan

Many researchers have focused on the role of sketching activity in design concept generation, and asserted that design is an iterative process of reflective interaction between thinking design concepts within designers' mind and externalizing them in verbal and drawing expression. Superposition of drawing is the typical operation in concept generation. Designers gradually shape an image by superposing, while concepts are gradually clarified. This paper proposes a knowledge-based sketch tool which manages a draw layer that is a unit of superposition and associates it with expressed design concepts. The sketch tool incorporates a concept network model, which integrates verbal and drawing expression. The tool automatically organizes alternatives of design concepts as well as alternatives of drawing so as to help a designer easily compare with each other and flexibly change an alternative. Those features facilitate designers to reflect the verbal and drawing expression. Its prototype is implemented by a knowledge-based design support framework named DRIFT which we have been developing. An example of coffee maker design is demonstrated in order to show the facility of the proposed tool.

## DESIGN EXPLORATION WITH USELESS RULES AND EYE TRACKING

**Jowers, Iestyn (1); Prats, Miquel (2); McKay, Alison (1); Garner, Steve (2)**

1: University of Leeds, United Kingdom; 2: The Open University, United Kingdom

Shape reinterpretation is an essential component in many domains of creative practice where processes of generation and exploration take place. But, computational design tools, such as computer-aided design systems, offer poor support for shape reinterpretation, and are not well suited to ideation in early stages of design. A key difficulty in implementing systems that support shape reinterpretation is the issue of interface – how can a user guide a system with respect to their interpretation of a shape? In this paper, a software prototype is presented that uses shape identity rules (so called 'useless rules') and eye tracking to support the creation and manipulation of shapes in the generative and explorative stages of conceptual design. The paper presents theoretical developments that have informed development of the prototype, including a summary reporting the outcomes of a series of eye tracking studies. The software prototype builds on results from these studies and uses gaze data and user input to restructure designed shapes so that they afford manipulation according to users' interpretations. It is suggested this work can significantly impact professional design practice.

## A NOVEL HYBRID 2D AND 3D AUGMENTED REALITY BASED METHOD FOR GEOMETRIC PRODUCT DEVELOPMENT

**Prieto, Pablo Andrés**

Universidad Técnica Federico Santa María, Chile

A method that uses the interaction of two and three dimensional environments to carry out the geometric modeling and refinement steps of the product development process is presented. The 2D environment is an interactive computer screen, where the initial sketching of the product takes place. This environment provides a direct one-to-one interaction and the feeling of using traditional pen and paper. Next, a characteristic feature of the 2D sketch is selected to be exported to a 3D environment, where 3D vision and manual interaction over an immersive augmented reality environment is provided to carry out the refinement steps. The 3D environment provides fully 3D visual feedback and geometry manipulation interaction. In this way, the advantages of 2D and 3D environments are used for a smooth transition between the sketching and the modeling tasks at the early stages of the design process.

The goal of this ongoing work is solving some limitations of the 2D nature of sketching, the speed constraints imposed by the transition between a 2D sketch and its digital 3D model representation and the limitations of current CAD systems to easily modify freeform surfaces under form development.

# Inspiration

Theme: Human Behaviour in Design  
Chair: Dorst, Kees

## UNDERSTANDING FIXATION: A STUDY ON THE ROLE OF EXPERTISE

**Viswanathan, Vimal; Linsey, Julie**

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Engineering idea generation plays a vital role in developing new products. Recent research has focused on methods to make designers more innovative and creative. Design fixation imposes a major constraint in this regard. This paper analyzes how design experience influences design fixation. This paper hypothesizes that people store more and more mental models into the set in their memory as they gain experience in creative design problem solving, and the extent of this set provides for both a greater set of solutions to draw from resulting in more ideas and may determine the extent to which they are fixated. A controlled laboratory experiment replicates the environment described in the study by Linsey et al. [1] with novices rather than experts, and compares the results to this prior study. The results support the increased number of ideas hypothesis but not the reduced fixation. It is observed that experts created significantly more ideas but also fixate more. Although the experts fixated on the example, they still outperform novices. This sheds light on the importance of a more practical-oriented approach in engineering curricula.

## AROUND YOU: HOW DESIGNERS GET INSPIRED

**Gonçalves, Milene Guerreiro; Cardoso, Carlos; Badke-Schaub, Petra**

TU Delft, Netherlands, The

Searching for sources for inspiration during the design process is a widespread activity and it is considered as a crucial step for most designers, independent of the degree of expertise. However, little is known about what designers use as sources for inspiration, and how they process such information to generate ideas and solve design problems. Whilst previous investigations have shown both the positive and negative effects of using particular visual sources for inspiration, there is a lack of information on other types of stimuli designers might use during idea generation. This paper presents the results of a questionnaire on novice and expert designers' preference regarding inspirational sources. Additionally, this study also encompasses both groups' selection of ideation methods for the generation of creative design solutions. Results show that whilst there are similarities between novices' and experts' responses, there are also clear differences in how they make use of available resources during idea generation. These findings unveil possible repercussions for design education on how designers search for inspiration.

## CHARACTERIZING REFLECTIVE PRACTICE IN DESIGN – WHAT ABOUT THOSE IDEAS YOU GET IN THE SHOWER?

**Currano, Rebecca M.; Steinert, Martin; Leifer, Larry J.**

Stanford University, United States of America

Innovation is in part driven by creative ideation, particularly in the fuzzy front-end of the design process, which has been described and studied as a process of reflection-in-action [1]. We introduce and explore the notion of Reflection-out-of-action, documenting it as a practice utilized by designers in coming up with new ideas, and contrasting it to Schön's concept of Reflection-in-action. We explore reflective design activities that occur on the level of the individual designer. Based on analyzing artifacts, surveying experts, conducting inductive and deductive conceptual framing rounds, and observing explorative experiments we were able to: 1) show evidence of various types of reflection in idealog artifacts; 2) identify and characterize reflective practices in use by designers; and 3) develop a framework for mapping reflective practices with respect to whether they take place in-action or out-of-action and whether they are driven by remembering or gathering.

## DESIGN-BY-ANALOGY USING THE WORDTREE METHOD AND AN AUTOMATED WORDTREE GENERATING TOOL

**Oriakhi, Edgar (1); Linsey, Julie (1); Peng, Xiaobo (2)**

1: Texas A&M University, United States of America; 2: Prairie View A&M University, United States of America

Design-by-Analogy is an approach that is widely embraced by designers seeking innovation. The identification of analogies is difficult, often spontaneous and not done by a systematic design process. The WordTree Method is a Design-by-Analogy method developed to systematically lead designers to functional design analogies. The WordTree Method is a relatively new design method and until now, WordTrees have been generated manually. This paper discusses a tool called the WordTree Express (WTE) that automates the generation of WordTrees. A controlled experiment presented in this paper shows that WTE positively influences designer's options and that designers can effectively use it to identify analogies. Recommendations for further work advancing the WordTree Method and contributions to Design-by-Analogy are presented in the concluding remarks.



ASSOCIATIVE THINKING AS A DESIGN STRATEGY AND ITS RELATION TO CREATIVITY

Casakin, Hernan

Ariel University Center of Samaria, Israel

Associative thinking can help designers to reflect over a problem situation by focusing on unrelated perspectives. During this process, a mapping of high order relations can be established between a source and a target situation. Associative thinking has much to contribute to design in general, and to design creativity in particular. This research centered on a particular form of associative thinking concerned with metaphorical reasoning. The aim was to analyze empirically the relation between associative thinking and creativity. A particular form of associative thinking based on the use of metaphors in the design studio was considered, and its relationship to the four standard creativity factors proposed by Gilford was explored. Results indicated that originality and elaboration were the most dominant factors characterizing metaphorical thinking during the design process. In contrast, fluency and flexibility were the weakest factors, poorly correlated with most variables of metaphorical thinking. Findings from this study have implications not only for design in general, but also for design education.

CREATIVITY TECHNIQUES FOR A COMPUTER AIDED INVENTING SYSTEM

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university of bergamo, Italy

The development of Computer Aided Inventing system, assisting product designer in their creative stage, is a lengthy process because lack of a real systematization of design knowledge for software implementation. The existing development tools for knowledge-based system offer limited support to intelligent design. In this paper, a knowledge-based architecture for igniting creative spark is described. It is aimed to solve those problems where a radical implementation is needed, not based on the improvement of previous inventions, but oriented to a new technological jump. Combining a selection of 3 different creativity approaches, mounted on the FBS ontology, the designer is forced to systematically generate a list of alternative systems achieving the same goal of the given one. All directions are then classified in form of a network tree on 3 levels: functional, behavioural and structural. A specific algorithm is then introduced to transform the network into an Information Extraction tool from patent DBs. Software can be uploaded as support for building patent technological surveys, personal knowledge database, technological transfer and forecasting.

PROBLEMS AND POTENTIALS IN THE CREATION OF NEW OBJECTS

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1: DTU, Denmark; 2: CBS, Denmark

In this paper we will based on two case studies, explore the creation of new objects in two very different contexts, being the art of painting and the fluid-mechanical engineering. From an empirical point of view we will treat creativity through actor-context relations, which enclose perceptions of problems. This kind of context is capturing a duality as both being a stabilizing structure, difficult to escape from, but also serving as the condition upon which to create something. This duality appears to be a critical and necessary condition for the creation of something new. Through different social theories we will argue the importance of problems in change-making processes. We will emphasize on how processes of creative thinking and innovation is done in steps, and how the end result reflects what these steps have brought in terms of problem perception and new knowledge. Inspired by concepts from Bruno Latour's science studies, we suggest a framework by which to understand how change is performed through systematical steps of materialization of problems, to gain the necessary support and acceptance to carry through innovation.

FACILITATING CREATIVE PROBLEM SOLVING WORKSHOPS: EMPIRICAL OBSERVATIONS AT A SWEDISH AUTOMOTIVE COMPANY

Lund, Katarina (1,2); Tingström, Johan (2)

1: KTH Royal Institute of Technology, Sweden; 2: Scania, Sweden

Being creative often includes putting ideas together in new combinations and approaching problems in new ways. It is a process which can be difficult and frustrating since it demands that we challenge our usual ways of thinking. Facilitation is one means by which we can be aided in the process of breaking our thought patterns, and thereby reach further in our creative efforts. This article describes the planning, execution, evaluation, and consequent lessons learned from the facilitation of two creative problem solving workshops. In these workshops four different groups addressed problem solving with a set of innovation tools and the help of a facilitator. Our conclusion is that a product development team, working interdisciplinary on creative problem solving may benefit from facilitation in different ways. We saw that facilitation can, for example help create mission clarity and counteract behaviour that may otherwise inhibit the participants' ability to come up with and share ideas. We also saw that entering a workshop with misleading preconceptions of workshop atmosphere may lead to insufficient time being spent on exploring potentially creative ideas.

MEANING-BASED ASSESSMENT IN CREATIVE DESIGN

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1: Ariel University Center of Samaria, Israel; 2: Tel Aviv University, Israel

The paper reports a novel approach to the assessment of design creativity by means of the meaning system. The introduction of main constructs of meaning corresponding to the theory of meaning by Kreitler and Kreitler, is followed by the presentation of theoretical and empirical considerations supporting the hypothesis that it is possible to assess design creativity in terms of the meaning system. An empirical study describing one specific set of meaning variables that were found to differentiate significantly between the more and less creative participants is described. The findings confirmed the expectation that this particular set of meaning variables of types of relations characterizes the more creative students as compared to the less creative ones. It was found that the more creative designers tended to focus on the personal-subjective meanings, as well as on some components of the interpersonally-shared meanings, whereas the less creative designers focused mainly on the interpersonally-shared meanings.

ANALYSING THE USE OF FOUR CREATIVITY TOOLS IN A CONSTRAINED DESIGN SITUATION

Snider, Chris (1); Dekoninck, Elies (1); Yue, Huang (1); Howard, Thomas James (2)

1: University of Bath, United Kingdom; 2: Technical University of Denmark, Denmark

This paper investigates creativity tools and their use within highly constrained design tasks. Previously, a coding scheme was developed to classify design changes as 'Creative Modes of Change'. The coding scheme is used to compare the outcomes from the use of four creative tools (supported design) against unsupported design within a constrained task. The tools showed design space expansion, developing additional concepts to those from the unsupported stage. All four tools stimulated 'Creative Modes of Change', although the type varied depending on their operation. 'Assumption Smashing' and the 'Contradiction Matrix' usually stimulate extra function; 'Analogies' and 'Trends of Evolution' improve design performance. The former two usually produce 'Creative Modes of Change' as opposed to routine. The results show some links between the designer's driving force, mode of change and the design outcome. 'New Requirements' as a driving force tend towards creative change and 'Change in Function'; 'Design Improvement' leads to less creative change and 'Change in Performance'. Hence a link may exist between the designer's driver, the design outcome, and the ideal tool to complete the task.

ENGAGING ACTORS IN CO-CREATING HETEROGENEOUS INNOVATIONS

Rosenqvist, Tanja Schultz; Lindegaard, Hanne; Jørgensen, Ulrik  
DTU, Denmark

In this paper we share and analyze our experiences staging a co-design process in which we through different interventions engage important stakeholders in designing. Our experiences are taking from a innovation and research project about user-involvement in textile design processes. As the project focused on textiles role in healing hospital environments, the co-design process analyzed is a process of designing textile products for these environments. During the co-design process we engaged architects, engineers and textiles designers. The focus in this paper is specifically on the challenges related to translating and transporting the results of these different events due to the institutional and professional framing of projects and design processes. We are analyzing these through an actor network approach to the process and use the translation term to describe how the participants slowly became engaged in our projects agenda by going through the different stages of translation. The paper is finalized with reflections on the difficulties in engaging actors in a co-design process and transporting results into the existing framed context of design and architectural work.

MONITORING A PROPERTY BASED PRODUCT DEVELOPMENT – FROM REQUIREMENTS TO A MATURE PRODUCT

Krehmer, Hartmut; Meerkamm, Harald; Wartzack, Sandro  
Universität Erlangen, Germany

Increasing customers’ requirements as well as changing market demands are just two examples for influences that result in an increasing complexity of technical products. To assure the fulfilment of all requirements an effective monitoring of product development is essential. Monitoring is often done by observance of required time and caused costs, and does not take into account product’s functionality, properties or behaviour. This contribution introduces a framework which allows combining different approaches for efficient monitoring of product development by focusing the products’ properties from requirements to a mature product. Therefore, at first a short introduction in property based product development is given and a model for property based development is introduced, before existing methods for evaluating and monitoring product development are depicted. After that an introduction in monitoring product development is given and approaches are integrated into the model of property based product development with regard to their capabilities and focuses. This results in an approach for a monitoring of property based product development from requirements to a mature product.

CAPTURING INTERACTIONS IN DESIGN PREFERENCES: A COLORFUL STUDY

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1: Bucknell University, United States of America; 2: Missouri University of Science and Technology

Many engineering and marketing tools exist to help a designer optimize quantitative attributes of a product, such as height, weight, volume, or cost. However, these methods cannot effectively take into consideration attributes for which there is a significant interaction between the product attributes with respect to the consumer’s preference, such as aesthetics. This research has begun the work of developing this necessary functional relationship for product attribute interactions and has created a methodology for further research. To accomplish this, this study considered consumer preference for product colors. Colors were represented by their red, green, and blue light components, and preference information for each of these attributes was gathered by presenting individuals with a small sample of colors, applied to backpacks, in a short choice survey.

USER CENTERED DESIGN IN THE WILD

Stompff, Guido (1); Henze, Lilian (2); Jong, Fred de (1); Vliembergen, Eddy van (1); Stappers, Pieter Jan (3); Smulders, Frido (3); Buijs, Jan (3)

1: Océ Technologies BV., Netherlands, The; 2: p5 consultants; 3: TU Delft, faculty of Industrial Design Engineering

Modern hi-tech product development is becoming increasingly complex, posing difficulties for achieving technically sound products, that also address the user needs. User Centered Design (UCD) methodologies have been developed, but are not easy to fit into modern industrial practice. We describe UCD practice in new product development (NPD) practice at Océ with a distributed R&D developing high tech products. The UCD professionals are embedded in NPD teams. Specifically we describe the social nature of product development in large close coupled teams, whereby the contribution of specialists is orchestrated whilst developing, and are enacted into prototypes. It was found that \_boundary objects\_ (like prototypes) that depict the intended outcome strongly contribute UCD, just as \_boundary experiences\_. These concern events that can be experienced and reflected on by all specialists involved. To orchestrate the contributions of specialists, a powerful tool is creating a \_product story\_. This is a coherent, plausible and shared narrative explaining what the product will be. Lastly it was found that \_synchronizing the natural UCD rhythm to the natural NPD rhythm\_ also enhances UCD.

SOLVING GLOBAL PROBLEMS USING COLLABORATIVE DESIGN PROCESSES

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In this paper we argue that use of collaborative design processes is a powerful means of bringing together different stakeholders and generating ideas in complex design situations. The collaborative design process was used in a workshop with international participants where the goal was to propose new solutions that would help solve the global problem of sanitation. Lack of sanitation is a problem for 42% of the world’s population but it is also a taboo topic that only very few people will engage in. In the one-day workshop participants from very different areas came together and brought forward proposed solutions for how to design, brand and make business models for how to solve aspects of the sanitation problem. The workshop showed that it was possible to work freely with such a taboo topic and that in particular the use of visualisation tools, i.e. drawing posters and building simple physical models strongly enhanced mutual understanding and exchange of ideas. Furthermore, the introduction of biological solution analogies also showed to be fruitful for the generation of new ideas for product design.

ENABLING SET-BASED CONCURRENT ENGINEERING IN TRADITIONAL PRODUCT DEVELOPMENT

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Set-Based Concurrent Engineering is described as an effective methodology for product development, but also hard to implement in companies using traditional development processes. This paper suggests a new way to introduce Set-Based Concurrent Engineering by combining its three principles with a modified Morphological chart. A structured process is proposed and incorporated in a computer tool based on templates. The approach is tested by using information from an industrial case study. The result indicates that the principles of Set-based Concurrent Engineering can be implemented in the proposed process and computer tool.

DESIGN FOR DIAGNOSIS

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Until now a large series of helpful guidelines for the design of products in the more concrete stages of design and product development were generated and published under the notion design for X, such as Design for Manufacture and Assembly (DFMA), Design for Cost (DfC), Design for Sustainability (DfS). Until now no special attention was given to design guidelines aiming at supporting designers to arrive at with products that allow and ease diagnosis – no special attention to Design for Diagnosis (DfD) guidelines. Only in the field of the design of highly integrated electronic modules attempts to employ DfD strategies were reported. The scope of the reported strategies is up to now limited to this field. The trend to ubiquitous computing and the first development steps towards cognitive systems as well as a general trend toward higher product safety and reliability lead to a higher importance of diagnosis, usually in order to detect possible faults in the products. In this paper a first attempt is made to formulate general valid guidelines how mechanical and electrical products can be designed in order to allow and to ease effective and efficient diagnosis.

DESIGN FOR DEPENDABILITY - IDENTIFYING POTENTIAL WEAKNESSES IN PRODUCT CONCEPTS

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The increasing competitiveness and the need to create innovative products force manufacturers to replace conventional technologies in their products by new technologies, thus injecting uncertainty in the design process. In this paper an existing design process of a smart memory alloy-actuator, representing the new technology, is analysed with regard to uncertainty and impacts on dependability. In order to systematically reduce the inherent uncertainty and to enable a dependability-oriented design process, a combination of a heterogeneous modelling approach and an “Inverse Functional Modelling” (IFM) method is presented. While the heterogeneous modelling approach enables a successive problem solving and helps the designer to intuitively model a product concept, the IFM method assists to identify non-intended functions and potential failures as well as disturbances at an early stage.

DESIGN FOR RELIABILITY: AN EVENT- AND FUNCTION-BASED FRAMEWORK FOR FAILURE BEHAVIOR ANALYSIS IN THE CONCEPTUAL DESIGN OF COGNITIVE PRODUCTS

Sop Njindam, Thierry; Paetzold, Kristin

Institute of Technical Product Development, University of the Bundeswehr Munich, Germany

Product complexity in modern engineering is rising at an ever-increasing rate for several reasons. On the one hand, designers are aimed at extending the functionality of products, thus, integrating them in human living environments and optimizing their interaction with humans. On the other hand, this functionality extension results from the synergetic integration of different disciplines. However, an important prerequisite for the market launch of these products is their ability to meet the previously defined requirements, particularly safety and reliability. In this perspective, we proposed a framework for the early analysis of the functional behavior of cognitive products. We assume that the failure of a function is linked with a system internal state transition. It is then possible to model the sequencing of different possible states, and by this means different functional failures which lead to critical feared states, thus, taking into account the random nature of the occurring failures. The approach presented is explained using an extended stochastic petri net with switching time to model the failure behavior of a cognitive walker

SELECTION OF PHYSICAL EFFECTS BASED ON DISTURBANCES AND ROBUSTNESS RATIOS IN THE EARLY PHASES OF ROBUST DESIGN

Mathias, Johannes; Kloberdanz, Hermann; Eifler, Tobias; Engelhardt, Roland; Wiebel, Marion; Birkhofer, Herbert; Bohn, Andrea

Technische Universität Darmstadt, Germany

Within this paper products are called robust, if uncertainties (property variations and disturbances) from production and use have no or little influence on the result during the use. In order to design products robust from the beginning of the design process, their design is to be carried out in a methodically supported Robust Design process (RD). Therefore, one has to be able to examine robustness already during the concept design. In order to support the concept design of the RD methodically, a catalog is developed here, in which the influencing disturbances are assigned to the single effects. Furthermore, three robustness ratios are defined. These are RI (disturbance based robustness ratio), RII (environment dependent robustness ratio) and RIII (sensitivity dependent robustness ratio). It is the goal of these ratios to enable a selection of physical effects with the help of their robustness based on different amount of information and effort within the early design phases. An exemplary appliance of the catalog and the ratios is carried out with the help of the design of a wrist watch.

LIFE CYCLE APPROACH TO SUPPORT TOOLING DESIGN DECISIONS

Ribeiro, Ines; Peças, Paulo; Henriques, Elsa

IDMEC, Instituto Superior Técnico, Portugal

The design and production of tools is a time consuming, technically difficult and expensive activity. Moreover, tool design choices highly affect the efficiency of the final parts manufacturing process in which they are used. Sometimes the least expensive tool does not lead to the least resource demand part production. It is then necessary to shift the paradigm from the cost of the tool as the main decision factor to the tool life cycle cost and even to other aspects not included in conventional costing. In this context, this research presents a new methodology to approach decision making in tooling design. It captures not only the conventional costs, but also more unattainable tooling aspects such as reliability. Moreover, as some cost items and unattainable aspects are differently valued by different stakeholders, these dissimilar perspectives are modelled and quantified in order to support a structured comparison between tooling design alternatives. The methodology will be applied to a case study in the moulding industry in order to exemplify its application.

MANUFACTURING COST ESTIMATION DURING EARLY PHASES OF MACHINE DESIGN

Germani, Michele; Cicconi, Paolo; Mandolini, Marco

Università Politecnica delle Marche, Italy

Machine design process requires the effective and rapid assessment of different design solutions. Beyond functions and technical performance other parameters as safety, manufacturability, assemblability etc. have to be taken into account. Manufacturing cost is one of the main factors in order to choose the most suitable solution, so accurate estimation in the early design phases is fundamental. Design to cost implies to manage a vast amount of manufacturing knowledge that has to be linked to the design parameters. Feature based 3D CAD models contain data useful for cost estimation but, despite the numerous researches on features recognition and extraction, no cost estimation software system yet assures reliable results. In such context, this paper presents an approach for rapid manufacturing cost estimation where design features are automatically linked to manufacturing operations. The approach has been implemented into a knowledge-based system and tested on practical case studies in order to validate the performance.



STEERING THE VALUE CREATION IN AN AIRPLANE DESIGN PROJECT FROM THE BUSINESS STRATEGIES TO THE ARCHITECTURAL CONCEPTS

Rianantsoa, Ndrianarilala; Yannou, Bernard; Redon, Romaric

EADS/ECF, France

The objectives of the designers have above all been the achievement of the aircraft mission and the certification rules. Today, the competition between airplane manufacturers leads to bring more added values to the stakeholders. Other types of values have then to be considered as higher level objectives like the ground operations and maintenance costs, the environmental impact, the image, the security and the autonomy. Therefore, the conceptual design must be driven in the perspective of value creation objectives from the first airplane specification sheet to a satisfactory dimensioned architecture. Consequently, the traceability of value contributions of design concepts to the entire airplane value should be better supported. An explicit enriched representation of the value model and the targeted stakeholders is then built. A strategical alignment transforms value targets into marketing business strategy and low level innovation strategies that drive design concepts development. This paper addresses all of these issues with a methodological proposal in four steps and based on a value based management of knowledge, design problems and design solutions.

SUPPORTING CYCLE MANAGEMENT BY STRUCTURAL ANALYSIS OF THE ORGANISATIONAL DOMAIN IN MULTI-PROJECT ENVIRONMENT

Elezi, Fatos; Pechuan, Alvaro; Mirson, Alexander; Bidermann, Wiland; Kortler, Sebastian; Lindemann, Udo

Technische Universität München, Germany

Today many companies involved in Product Development usually run several development projects at a time. This multi-project environment increases the complexity that the management has to deal with, especially in managing the high amount of iterations (cycles) that are inherent in Product Development projects. In many cases, the management does not have an overview on how and in what amount different departments are being involved in these cycles. This paper introduces a Multi-Domain Matrix (MDM) based methodology for obtaining a snap-shot overview of the level of involvement and interaction between different functional departments. The result of this methodology is an organizational map of development departments (organisational portfolio) that provides information to the management on how particular functional departments are involved in the development processes as well as the level of interaction with other departments and suppliers in the multi-project environment. Based on this information, managers can reach decision on how to improve the information flow between these teams, which supports cycle convergence and consequently reduction of cost and time to market.

DESIGN DRIVEN PORTFOLIO MANAGEMENT

Petersen, Soren Ingomar; Steinert, Martin; Beckman, Sara

ingomar&ingomar - consulting, United States of America

Design practice and anecdotal evidence point to the existence of a chasm between business plan generation and the execution. The failure to including vital industrial design criteria in these plans prevents portfolio managers from managing risk effectively. At the same time, the gap between design team and portfolio manager hinders the communication of these criteria to the design team, jeopardizing the execution. Concepts that cross that chasm are well informed by business plans and consist of a comprehensive industrial design philosophy and results in a well balanced design discourse. We have established a best practice for design briefing and formulated the "Design Driven Portfolio Management" method. This method comprehensively evaluates, maps and communicates business and industrial design opportunities throughout the organization. The validity of the approach is established by applying the method to firms' innovations in the design of products based on sustainable and disruptive technologies as test cases. We conclude that design brief content and concept performance correlate with innovation types and can be mapped and managed using our method.



INSIDE A PSS DESIGN PROCESS: INSIGHTS THROUGH PROTOCOL ANALYSIS

Sakao, Tomohiko (1); Paulsson, Svante (1); Mizuyama, Hajime (2)

1: Linköping University, Sweden; 2: Kyoto University, Japan

Product/Service Systems (PSS) has been addressed as an interesting research target in the engineering design community. Yet, an understanding of PSS design processes is scarce. Motivated by this gap, this paper aims to analyze, through a descriptive study, the details of the entire process of a PSS design case, and thus contribute to a better understanding of PSS design processes. To do so, an example of PSS design was conducted by three people working as a group using a modelling scheme called PSS Layer Model. Then, this design episode was analysed through protocol analysis. The results of the analysis include two reasonable hypotheses. First, PSS design follows a general process of problem solving. Second, it begins with need and value for a customer, addresses mainly lifecycle activities for solutions, and ends back with value. In addition, lifecycle activities might be given a central role within PSS design. However, it should be emphasized that the analysis of PSS design needs to be carried out further with more cases in order to create more robust knowledge.

INTEGRAL DESIGNED DATABASE MORPHOLOGY FOR ACTIVE ROOFS

Zeiler, Wim

Technical University Eindhoven, Netherlands, The

Lack of collaboration in design teams often results in a low mutual level of understanding about the design to produce. Especially the collaboration between designers and contractors is difficult resulting in sub-optimal design solutions and problems in construction. To improve that design phase was one of the aims of the 6th European Research Project 'Euractive Roofer: develop tools to support designers and specialized roof-contractors in the setting of collaborative design to create innovative' active' roofs. The concept of the web-based database is explained by its lay-out and functioning and is discussed through the results and insights gained by the Euractive Roofer-workshop with practitioners from the Dutch Construction Industry.

APPLYING CONTEXT TO ORGANIZE UNSTRUCTURED INFORMATION IN AEROSPACE INDUSTRY

Xie, Yifan (1); Culley, Steve (1); Weber, Frithjof (2)

1: University of Bath, United Kingdom; 2: Airbus

A large portion of information created in business activity is unstructured with much useful information buried inside. Within the aerospace industry, an added challenge is that long product lifecycles require such unstructured information to be accessible over a long period of time. In this paper, the authors have examined and identified promising techniques that can collectively contribute to better organization of unstructured information. Two industrial case studies were conducted to examine current practices of organizing unstructured information in respective engineering departments. As a result, key challenges in organizing and dealing with the unstructured information elements within engineering setting are identified. Subsequently, a set of requirements of a desired intelligent system is developed. These requirements are then used to guide the design of an example Context Based Search Platform which demonstrates promising potential for dealing with multi-dimensional and complex data sets that all engineers have to deal with.

CHALLENGES IN SEMANTIC KNOWLEDGE MANAGEMENT FOR AEROSPACE DESIGN ENGINEERING

Sanya, Isaac (1); Shehab, Essam (1); Lowe, Dave (2)

1: Cranfield University, United Kingdom; 2: Rolls-Royce, Derby, United Kingdom

The efficient and effective management of knowledge is becoming increasingly important within the aerospace design engineering sector due to the complexity of product development. The ongoing collaboration of multidisciplinary specialist skills is of necessity for the development of advanced and complex products throughout the aerospace sector. This paper presents various challenges that could hinder the management of knowledge within the aerospace design engineering environment. Furthermore, this paper demonstrates that ontological engineering for semantic knowledge management has been proven to be an effective means of structuring and organising complex knowledge. However, various challenges such as the ambiguity of vocabulary, no shared agreement of meaning between design and manufacturing engineers, no formal notation for representing ontologies and engineers not willing to utilise ontological tools for structuring knowledge are detrimental issues hindering the effective management of knowledge within aerospace design engineering.

MODELING AND MANAGEMENT OF PRODUCT KNOWLEDGE IN AN ENGINEER-TO-ORDER BUSINESS MODEL

Elgh, Fredrik

Jonköping University, Sweden

To adopt an engineer-to-order (ETO) business model when competing on a market where competitors' products are mass-produced is a challenge. However, a competitive edge can be gained if the principles of ETO and mass production successfully can be combined. High level of customer adaptation requires systems for efficient generation of product variants with associated specifications for automated manufacturing. To maintain these systems's usefulness over time, frequent updating will normally become a necessity. Of equal importance, is the reuse of the system encapsulated generic product family objects when developing a new product family. In this paper a case study is presented with the main objective to provide a system foundation for modeling and management of product knowledge supporting reuse, expansion and maintenance of system embedded objects. One of the central parts of the framework is the Meta-Knowledge Containers, labeled Descriptions for the case company. A Description contains both a definition of system embedded objects as well as the rationale behind their design. Traceability is gained by linking of Descriptions, individually and to documents, models and items.

# System Modularity

Theme: Product and Systems Design  
Chair: Fukuda, Shuichi

## AN APPROACH FOR MORE EFFICIENT VARIANT DESIGN PROCESSES

**Schubert, Sebastian; Feldhusen, Jörg; Nagarajah, Arun**

*RWTH Aachen, Germany*

Today, as a result of a steadily increasing pressure to reduce costs in the automotive supply industry, the majority of the products are designed by adapting already existing products. In the embodiment design phase, CAD models are taken as the design base and adapted. Changes made over generations of product variants make the models more and more complex and unstructured, causing more effort for adaptation. Further capability to reduce costs is found in the design process. Mandatory analyses, like the FMEA, are redone completely, although the product remains similar. In order to reduce the effort, standardized system elements are introduced into the FMEA being adapted to the new requirements of a new order. Furthermore, functions and parameters being elaborated by executing the FMEA are reused in the embodiment design phase. The approach presented here shows how function structures and parameters derived from the FMEA are used to manipulate a skeleton model in the CAD environment. The skeleton model provides the main constraints for the part design. A method is presented how the embodiment design of those products is simplified using parametric and direct modeling techniques.

## MODULARITY WITHIN A MATRIX OF FUNCTION AND FUNCTIONALITY (MFF)

**Zadnik, Žiga (1); Čok, Vanja (1); Karakašić, Mirko (2); Kljajin, Milan (2); Duhovnik, Jože (1)**

*1: Faculty of Mechanical Engineering, University of Ljubljana, Slovenia; 2: Mechanical Engineering Faculty, J. J. Strossmayer University of Osijek, Croatia*

The objective of this paper is to present the concept of modularity in the development of a product by means of the descriptive matrix of function and functionality (MFF), based on the generative model and criteria for describing products, functions and functionalities. The purpose of using the modularity of the descriptive MFF is to improve the initial design process where only the most basic information is available, such as functions and functionalities, and to use the general functionality method, which is not quite possible with the morphological matrix. Modularity inside the MFF is based on mutual relation between the function and functionality, representing the data definition. In relation to the morphological matrix it is built and defined on the basis of a mathematical model and pre-set rules [1], not only on the basis of design intuition. This work represents a method of solving modularity with regard to shape and function. This should facilitate generating functional and shape structures of new and variant products. The developed MFF modularity model has been implemented into a prototype web application and confirmed on a concrete product – Active Lounge Chair 1.

## DEVELOPMENT OF MODULAR PRODUCTS UNDER CONSIDERATION OF LIGHTWEIGHT DESIGN

**Gumpinger, Thomas; Krause, Dieter**

*Hamburg University of Technology, Germany*

Whether it is the reduction of complexity during development or the individual configuration for the consumer, modular products do offer many benefits throughout their product lifecycle. Hence it is not surprising, that many products are based upon this principle. Along with this modularisation aspect the tendency to lighter, more efficient products gets substantial. Especially the lightweight design of moving masses, for example in the transportation sector, is crucial. But when these two principles come in conjunction the design conflicts between them are hardly to resolve. At last modularised products tend to be heavier than non-modular products. To overcome this conflict is an important step to serve the individual consumer and to comply with environmental responsibility of the society. In this paper the effects of modularisation on lightness design are outlined. Subsequently a strategy is presented to handle the identified drawbacks of modularisation on lightweight design.

## A CLASSIFICATION FRAMEWORK FOR PRODUCT MODULARIZATION METHODS

**Daniilidis, Charalampos; Ensslin, Vincent; Eben, Katharina; Lindemann, Udo**

*Technische Universität München, Institute of Product Development, Germany*

The modularization of product architectures and the standardization of components and modules across a product family or product portfolio constitute approaches to reduce the internal variety in an enterprise while keeping the range of the external variety. Thus costs and development time can be reduced through scale effects and further transparency within the product portfolio can be enhanced as well. In this context a plethora of methods and approaches to identify modules in product architectures has been introduced. These methods differ in the application area and the procedure and show different benefits and weaknesses. This paper introduces a classification framework for modularization methods and approaches that provides a systematic overview on past and current developments. Therefore an extensive literature survey on modularization was carried out to identify the major methodologies introduced in the last years.

# Computational Design Synthesis

Theme: Design Methods and Tools  
Chair: Papalambros, Panos Y

## ADVANCED APPLICATIONS OF A COMPUTATIONAL DESIGN SYNTHESIS METHOD

**Bolognini, Francesca (1); Shea, Kristina (2); Seshia, Ashwin (1)**

*1: University of Cambridge, United Kingdom; 2: Technical University of Munich, Germany*

From modelling to manufacturing, computers have increasingly become partners in the design process, helping automate many phases once carried out by hand. In the creative phase, computational synthesis methods aim at facilitating designers’ tasks through the automated generation of optimally directed design alternatives. Nevertheless, applications of these techniques are mainly academic and industrial design practice is still far from applying them routinely. This is due to the complex nature of many design tasks and to the difficulty of developing synthesis methods that can be easily adapted to multiple case studies and external automated simulation. This work stems from the analysis of implementation issues and obstacles to their widespread use found in previous research on synthesis methods. The research investigates possible improvements to these methods through the application of a novel technique to complex design tasks. The ability of this technique to scale-up without sacrificing accuracy is demonstrated. The successful results confirm the possibility to use synthesis methods in complex design tasks and spread their commercial and industrial application.

## AN APPROACH FOR THE AUTOMATED SYNTHESIS OF TECHNICAL PROCESSES

**Stankovic, Tino (1); Shea, Kristina (2); Storga, Mario (1); Marjanovic, Dorian (1)**

*1: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia; 2: Technical University of Munich, Institute of Product Development, Germany*

This paper considers the implications of introducing the computational method for technical process synthesis founded on the Theory of Technical Systems as an addition to the current Computational Design Synthesis (CDS) methods and tools. A computational method containing formal model of technical process based on labelled multidigraph and formal model of technical process synthesis that is based on labelled multidigraph graph-grammar transformations will be presented. The result of applying transformation to the multigraph is generation of variants showing how technical process could be accomplished.

## HIERARCHICAL SYSTEM CONCEPT GENERATION

**Rosenstein, David; Reich, Yoram**

*Tel Aviv University, Israel*

The most important stage in a product life cycle is the conceptual design which involves uncertainty but also opportunity. The SOS method of generating product design alternatives [1] is expanded here to introduce more information to help reduce uncertainty and explore design solutions to better suite customer requirements, market conditions, and the use of current technology. Hierarchical SOS uses two levels of building blocks: the 1st level contains major building blocks (the same as in regular SOS) and the 2nd level contains slightly more detailed articulations of the building blocks of the 1st level. The product requirements are cascaded to the 2nd level and are translated to secondary targets. The search of the best product design alternatives is done by a genetic algorithm (GA). As expected, the new information introduced and manipulated at the 2nd level turns out to be critical for creating good conceptual designs.

## ELISE 3D - A DATABASE-DRIVEN ENGINEERING AND DESIGN TOOL

**Maier, Moritz**

*IMARE - Institute for Marine Resources GmbH, Germany*

Realizing completely new functional design approaches one has to deal with different geometries, materials and construction methods. The acquisition of the needed data for a totally new initial model is complex and therefore design of light structure is typically done by changing or optimizing existing solutions. The database-driven engineering and design tool ELiSE uses marine plankton organism as archetypes. Since about 100.000 different species with different light structure geometries are known, a systematic use of this pool of potentially technically usable structures is consequential. As a result unique design solutions can be found efficiently and integrated to a consisting workflow.

Designing a Spaceship for Everyone: A new technology and market that is out of this world!



Jonathan Firth  
Operations & Projects Director  
Virgin Galactic

Abstract

Virgin Galactic has been established as a commercial spaceline to provide safe and affordable access to space for people, science and payload. In the first instance, it will transport space tourists on a sub-orbital spaceflight experience, during which they will be able to experience weightlessness for several minutes. Achieving this has already involved overcoming several significant design challenges; a two-stage spaceflight system has been designed, with a spacecraft being released from its mothership at altitude and the spacecraft subsequently deploying a novel means of achieving safe re-entry to the Earth's atmosphere. In addition, the prototype design for the spacecraft, which was flown by a lone pilot into sub-orbital space in 2004, has been scaled up to include a passenger cabin large enough for Virgin's commercial flights to carry six passengers. The spacecraft design has also been thoroughly overhauled to provide the spaceflight experience that Virgin's early research identified as essential to delivering the required customer experience and thereby establishing a sustainable business. This presentation will summarise the main cross-discipline challenges that Virgin is working to overcome and the progress made so far on its plans to turn commercial space travel into a reality.

Biography

Jonathan Firth has been involved in the Virgin Galactic initiative from 2004, first as Project Director and then as Projects and Operations Director since the beginning of 2008. In his current role his responsibilities include: the Spaceflight System Development Program being undertaken by Scaled Composites; the activities of The Spaceship Company, which has been established to build further spaceflight vehicles, initially for Virgin Galactic; the relationship with the New Mexico Spaceport Authority, which is overseeing construction of Spaceport America, the future home of Virgin Galactic's suborbital spaceliner fleet; and ongoing operational activity to ready Virgin Galactic for its start of commercial operations. Jonathan first joined the Virgin Group in 1998 as Virgin Trains' Project Director and was responsible for delivery of the Pendolino and Voyager tilting train projects. After that, he spent three years as Director of Projects at Virgin Atlantic Airways, where he was responsible for overseeing the airline's portfolio of business-led projects. Before joining Virgin, Jonathan enjoyed a diverse career in projects and project management. He has worked in Oil & Gas, Petrochemicals, Mass Transit, Main Line Rail, Aviation and Aerospace, and holds an honours degree in Mechanical Engineering from Imperial College London and an MBA from Henley.

The Future of Innovation - Beware of the Dark Side



Bettina von Stamm  
Director & Catalyst  
Innovation Leadership Forum

Abstract

Innovation is on the agenda. It does not matter whether your organisation is small or large, whether you work in industry academia or government, or whether you work in the third sector: innovation is today's mantra. It seems to have become the holy grail everyone pursues (with varying degrees of success). We all get excited by the potential and possibilities innovation seems to offer. The presentation will ask whether there might be a dark side of innovation. We certainly need to think about innovation, a lot. But perhaps not quite as we know it, and the way we are used to. The presentation will challenge whether we join the quest for innovation too lemming-like, whether innovation has indeed become an end in itself rather than being a means to an end. It will close with proposing some armoury and companions that might help keep the quest for the innovation grail on the right tracks.

Biography

For the past 20 years Bettina has been a visionary and original thinker at the boundary between business and academia, working in the field of her passion: innovation. While she values academic rigour, her main concern is practical relevance. During her independent career she has always taken great pleasure and pride in combining and balancing a number of different activities such as research, teaching, writing, running networking initiatives and engaging in public speaking. Having worked independently in the field of innovation since 1992, in 2004 she set up the Innovation Leadership Forum (ILF, [www.innovationleadershipforum.org](http://www.innovationleadershipforum.org)).

She also enjoys writing; while generally based on research, Bettina focuses on the practitioner audience; in addition to numerous articles she has published three books and one major industry report:

- The Future of Innovation – in which Dr Anna Trifilova and herself have knitted together the thoughts, dreams, hopes, fears and wishes of over 200 leading thinkers in the innovation community (Gower, 2009, 2010); see also [www.thefutureofinnovation.org](http://www.thefutureofinnovation.org).
- Managing Innovation Design & Creativity – is a text book structured around 12 case studies and 22 chapter that cover a broad range of innovation-relevant topics; also available in simplified Chinese (Wiley, 2008, 2nd ed).
- The Innovation Wave - for general managers, those who want to start on their 'understanding innovation journey', and those who appreciate a holistic approach to innovation (Wiley, 2002).
- The 4th Innovation Best Practice & Future Challenges Report - drawing on interviews with leading innovation practitioners and 20 years of experience in the field of innovation; self-published.



WRITING, REVIEWING AND PUBLISHING SCIENTIFIC PAPERS IN DESIGN

Moderator: Jean-Francois Boujut (Organiser of the Grenoble Design Journal Editor Workshop)

Panelists

- Tetsuo Tomiyama (TU Delft, Editor of Advanced Engineering Informatics, Elsevier)
- Yoram Reich (Tel Aviv University, Editor of, Research in Engineering, Springer)
- Alex Duffy (Strathclyde University, Editor of Journal of Engineering Design, Taylor & Francis)
- Panos Papalambros (University of Michigan, Editor of ASME Journal of Mechanical Design)

Purpose

Pressure on scientific publications has become significant in the academic world. For junior researchers, writing a scientific paper is paramount to anything else and needs to be mastered very quickly during their early carrier stage. Usually what is offered by universities, however, is very generic training courses and not specifically tailored for design researchers.

On the other hand, since nowadays junior researchers write so many papers, the demand for competent peer reviewers is enormous. However, junior researchers don't know how to write good reviews and senior researchers often don't have time to do good reviews. From the viewpoints of both authors and editors, reviews must be effective and efficient, i.e., useful, constructive and concise. In fact, writing a good review itself is the opposite side of the coin, i.e., writing a good paper.

In this workshop, four editors-in-chief of design related scientific journals will tell participants how to write good design research papers, how to write good reviews, and useful information about scientific publications in a workshop format. Besides presentations given by these editors, there will be ample time for questions and answers.

Programme

- Introduction to the workshop, aim, who should attend (Boujut)
- Basic information about each journal
  - Tomiyama (Advanced Engineering Informatics)
  - Reich (Research in Engineering Design)
  - Duffy (Journal of Engineering Design)
  - Papalambros (Journal of Mechanical Design)
- Essential elements for a paper to be accepted by each journal
  - Tomiyama (Advanced Engineering Informatics)
  - Reich (Research in Engineering Design)
  - Duffy (Journal of Engineering Design)
  - Papalambros (Journal of Mechanical Design)
- Essential elements of an excellent review
  - Tomiyama (Advanced Engineering Informatics)
  - Reich (Research in Engineering Design)
  - Duffy (Journal of Engineering Design)
  - Papalambros (Journal of Mechanical Design)
- Summary, discussions, Q&A



AI EDAM Special Issue on Functional Descriptions

Date: Wednesday 17 Aug 2011  
Time: 13:15-14:15  
Location: Workshop Room s08  
Chairs: Claudia Eckert & Pieter Vermaas

Decision Making SIG meeting

Date: Wednesday 17 Aug 2011  
Time: 13:15-14:15  
Location: Workshop Room s16  
Chairs: Sandro Wartzack & Julie Stal-Le Cardinal

Collaborative Design

Date: Wednesday 17 Aug 2011  
Time: 13:15-14:15  
Location: Workshop Room s04-05  
Chairs: Avril Thompson & Ian Whitfield

Journal of Engineering Design Editorial meeting

Date: Wednesday 17 Aug 2011  
Time: 13:15-14:15  
Location: Workshop Room s06  
Contact: Sophie Neal

Design Society AB meeting

Date: Thursday 18 Aug 2011  
Time: 13:15-14:15  
Location: Workshop Room s08  
Chairs: Warren Seering & Chris McMahon

IPD Workshop meeting

Date: Thursday 18 Aug 2011  
Time: 13:15-14:15  
Location: Workshop Room s16  
Chair: Sandor Vajna

CURRENT RESEARCH AND FUTURE DIRECTIONS

Chairs: P. John Clarkson (University of Cambridge), Sandor Vajna (Otto-von-Guericke-Universität Magdeburg)

About the workshop

Engineering processes are the “glue” that hold the activities within product development and design together. Engineering processes structure these activities appropriately, secure their reasonable processing, and ensure the correct and timely use of the appropriate approaches & procedures, methods, data, and tools in order to improve the design process, improve products and services, and properly document product development processes and the products themselves. It is the aim of this group to contribute to a smart and smooth definition, application, and navigation of Engineering Processes within the scope described above. Our membership is a diverse group of academics, researchers and practitioners from different industries.

Programme outline

- 14:15

Welcome
- 14:25

Brief summaries of activities since workshops in Dubrovnik and Stanford

  - MMEP Conference, Cambridge, UK (John Clarkson)
  - IPD Workshop, Magdeburg, Germany (Sandor Vajna)
  - MMEP EU Practitioners’ Group Workshops (Peter Heisig)
- 14:45

Presentation of a number of selected papers, followed by a discussion of the work presented. Papers will be selected to provide a coherent platform for debate.
- 15:45

Break
- 16:15

Discussion continues
- 17:00

Discussion on the next steps for the development of the SIG, reflecting on future events, future management of the SIG and further development of the SIG community through targeted collaborative research.
- 17:45

Close

Additional information

Please check the MMEP website at <http://www-edc.eng.cam.ac.uk/mmep/> for:

- MMEP research road map “Challenges and Future Fields of Research for Modelling and Management of Engineering Processes”(CUED/C-EDC/TR 148 ISSN 0963-5432)
- Please check also the SIG MMEP Conference webside at [www.mmep-conference.org](http://www.mmep-conference.org) for:
- MMEP2010 Conference Newsletter
  - MMEP2010 Conference Proceedings: Heisig, P., Clarkson, P.J., Vajna, S. (Eds.) Modelling and Management of Engineering Processes. Springer Publisher, London, 2010, ISBN 978-1-84996-198-1;
  - Posters & Software descriptions: CUED/C-EDC/TR151 ISSN 0963-5432



ADVANCEMENT AND CONVERGENCES

Chairs: Armand Hatchuel (Mines ParisTech) and Yoram Reich (Tel Aviv University)

About the workshop

The goal of the workshop is to present to ICED attendees the activities of the SIG, its goals and achievements since its inception, and particularly in the last year, in order to attract new members and obtain feedback from the audience regarding the SIG goals and agenda. Two presentations deals with this aspect: a state-of-the-art review and recent advances of design theory and a historical analysis of the relation between design theory and creativity. This presentation also aims to further the connection between the theory and creativity SIGs.

In addition, the SIG meeting will feature two areas with research opportunities. The first presentation involves a presentation of design in emerging economies – an issue that might need the attention of design theory and the second is a panel on a critical methodological aspect in the development of design theories – conducting theory driven experiments.

Agenda

- 14:15 -

State of the art and advances in design theory (A. Hatchuel and Y. Reich)
- 15:15 -

Design theory and creativity: a historical approach (P. Le Masson, B. Weil, and Y. Nagai)
- 15:45 -

Break
- 16:15 -

Innovation and design in emerging economies (E. Subrahmanian)
- 16:45 -

Theory driven experiments in Design: panel discussion (J. Edelman, A. Kazakci, M. Agogue)
- 17:15 -

Guest lecture and open discussion on SIG DT future work



# Research Methods for Studying Designers

Theme: Design Theory and Research Methodology  
Chair: Blessing, Lucienne T.M.

## DESIGNER BEHAVIOUR AND ACTIVITY: AN INDUSTRIAL OBSERVATION METHOD

Cash, Philip (1); Hicks, Ben (1); Culley, Steve (1); Salustri, Filippo (2)

1: University of Bath, United Kingdom; 2: Ryerson University, Canada

The relationship between laboratory based study and the actual practice of engineering design is very important. For research activity, laboratory based studies have an important role. The problem is the difficulty of relating laboratory to practice, it is thus important to fully understand this relationship. To address this, an observational method is proposed that focuses on characterizing the activities and behaviors of designers in practice. The method has been developed to provide rich context, whilst avoiding information overload. The proposed method is then critically discussed with respect to the issues particularly affecting empirical design research, such as contextualization, validity and repeatability. Finally, the paper highlights the potential importance and impact of the method for developing the relationship between practice and laboratory based experiments.

## MODELING PARADOXES IN NOVICE AND EXPERT DESIGN

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In their ICED09 paper ‘Problem formulation as a discursive activity’, the authors have used an extensive educational case study to explore a framework for describing design as a discursive activity, centered around the paradoxical nature of the problem situation. The ‘working definition’ for paradox that was used as the basis of that paper will now be re-examined, extended and detailed in the light of studies on expert designers. In particular, paradoxes will now be situated as an opposition between frames or within frames. Expert designers can be seen to build up a rich picture of the frames at play in a design situation, and extract themes that can lead to reformulation of the problem as well as the creation of innovative solutions. This behaviour is compared to the ways of working of novice designers (students) in the original case study.

## LINKOGRAPHER: AN ANALYSIS TOOL TO STUDY DESIGN PROTOCOLS BASED ON FBS CODING SCHEME

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This paper presents LINKOgrapher, a software tool that carries out analyses on coded design protocols. LINKOgrapher is implemented building on an ontologically-based coding scheme utilising the Function-Behaviour-Structure (FBS) ontology. It aims at enabling cross-comparisons of different protocol studies through utilising a re-usable coding scheme and standardizing the analysis methods. Current measurements include tabular statistics, dynamic modeling of design issues and design processes, Markov models, first passage models and entropy models. The calculation and visualization of the results on screen is near real-time, saving time and effort needed to analyse long design protocols. The results are exportable as graphic models as well as textual outputs. The measurement procedures and features of LINKOgrapher are discussed along with exemplary results.

## TOWARD AN ADAPTION-INNOVATION STRATEGY FOR ENGINEERING DESIGN

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1: BMGI, United States of America; 2: Penn State Great Valley

A cognition based strategy for linking the variables that affect product design and development are illustrated with the help of a new Cognition-Based Design (CBD) framework. This paper briefly introduces the Cognition-Based Design (CBD) framework and demonstrates how the adaption-innovation style of individuals can be used as a strategy to be applied to design opportunity, design process, designer’s problem solving functions, design environment and the resulting product. The outcomes of product design activities can be greatly influenced and managed by the application of adaption-innovation strategy to each key variable. Some exploratory data from simulated application of adaption-innovation theory on design engineers within industry are discussed. Recommendations for making use of the new strategy to design activities are provided, as well as suggestions for future research.

## THE IMPACT OF EXAMPLES ON CREATIVE DESIGN: EXPLAINING FIXATION AND STIMULATION EFFECTS

Agogu  , Marine; Kazak  i, Akin; Weil, Benoit; Cassotti, Mathieu

Mines ParisTech, France

Converging evidences have indicated that the ability to generate creative ideas could be limited by recently activated knowledge such as examples of solutions. However, neuroimaging studies have recently demonstrated that exposure to examples did not systematically lead to fixation and could on the contrary have a stimulation effect on creativity. Our hypothesis is that there are two types of examples that C-K theory helps to characterize: (1) restrictive examples that do not change the definition or the attributes of the object, and (2) expansive examples that modify its identity by adding unexpected attributes. In two studies, we explored the impact of restrictive and expansive examples on a creative task. We then hypothesized that the introduction of an example during the task would provoke participants to propose solutions of a higher originality when the provided example was expansive. In contrast, when the provided example was restrictive, we hypothesized that the originality of the solutions would be reduced. Results confirmed that solutions proposed by the group exposed to restrictive example are less original than those given by groups exposed to expansive examples.



AN AGENT-BASED SYSTEM FOR SUPPORTING DESIGN ENGINEERS IN THE EMBODIMENT DESIGN PHASE

Kratzer, Martin; Rauscher, Michael; Binz, Hansgeorg; Goehner, Peter  
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Today, product development is dominated inter alia by a complex and interdisciplinary working environment. As a consequence, several problems come up: design engineers need a huge amount of knowledge to design high quality products, non-compliance with basic requirements and non-compliance of machine elements with different design guidelines like Design for X. One possibility to overcome these problems is the use of knowledge-based systems in engineering design. This paper follows a different approach: the use of an agent-based system in combination with a CAD System to support design engineers in the embodiment design phase. Because of its novelty, this approach has to be investigated and several problems have to be tackled. Firstly, it is not clear in which way the ABDS has to be built up. Secondly, there is no structured method for integrating engineering design knowledge into ABDSs. Due to these two problems, there is no generic procedure for developing these ABDSs. Answers regarding these problems will be given in this paper.

IT SUPPORT FOR THE CREATION AND VALIDATION OF REQUIREMENTS SPECIFICATIONS – WITH A CASE STUDY FOR ENERGY EFFICIENCY

Reichel, Thomas; Rünger, Gudula; Steger, Daniel; Xu, Haibin  
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Complete, clear, and valid requirements specifications are the foundation for a successful product development. For technical products, these specifications have to take into account several factors, including customer needs, the market, governmental regulations, international standards, and manufacturer-specific policies. Lately, the environmental impact of products has become an additional important factor. Various domain experts are necessary to cope properly with all these factors and, therefore, IT support for creating and validating requirements specifications is highly recommended. This article proposes a workflow that supports the creation and validation of requirements specifications as well as the collaboration between domain experts. The workflow utilizes existing approaches of requirements management in the engineering domain and can be used for an appropriate IT support for the validation of completeness, integrity, and consistency of requirements specifications. A reference architecture for an IT solution implementing the workflow and the corresponding IT support is proposed. In a case study, the workflow is applied to the requirement \_increase energy efficiency\_.

APPRICATION TO A CAR BODY FRAME BASED ON PARAMETER GUIDELINES FOR DERIVING DIVERSE SOLUTIONS USING EMERGENT DESIGN SYSTEM

Sato, Koichiro; Matsuka, Yoshiyuki  
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In the early design process, diverse design ideas are generated from a global solution search under unclear design conditions. Because it is difficult to apply conventional engineering design in the early design process, the emergent design system capable of generating various three- dimensional forms is proposed. Although this system appropriately set the parameters in every application cases, the system cannot determine whether the values of the obtained parameters are the best because the parameters are selected by trial and error. The research herein extracted the parameters that influence the diversity of form with the goal of devising the emergent design system that uses these extracted parameters to generate forms. Then these guidelines in this emergent design system were applied to a car body frame design. The results demonstrate that diverse solutions satisfying the mechanical properties can be derived, and thus confirm the usefulness of the guidelines.

A DECOMPOSITION ALGORITHM FOR PARAMETRIC DESIGN

Jauregui-Becker, Juan Manuel; Schotborgh, Wouter Oliver  
University of Twente, Netherlands, The

This paper presents a recursive division algorithm to decompose an under constraint parametric design problem. The algorithm defines the separation of the problem at the hand of two complexity measures that are calculated for each parameter in the problem, namely, the effort E and the influence Inf. The result from applying this algorithm is a sequence indicating the order in which parameters can be instantiated by, for example, a random value generator, or be calculated by using an equation. The characteristic of this algorithm is that it considers the structure of the equations in the problem to derive a solving strategy instead of considering its mathematic details. The advantage of doing so, from a design point of view, is that the algorithm is not limited to handling any specific types of equations (like for example pure algebraic or differential). In opposition, the algorithm is capable of handling different combinations of types of knowledge for determining a solving procedure.

A VISUALIZATION CONCEPT FOR SUPPORTING MODULE LIGHTWEIGHT DESIGN

Gumpinger, Thomas; Jonas, Henry; Plaumann, Benedikt; Krause, Dieter  
Hamburg University of Technology, Germany

In the aviation industry there is a current trend towards modular product design. As usual in aviation design, weight is a crucial factor. Therefore a modular product should not outweigh a former non modular product with an identical functionality. The modules have to be very light to compensate the additional weight due to module interfaces in order to fulfill its demands. With the increasing need for a lighter design the complexity for finding weight optimization potential increases. We present an easily usable visualization approach for reducing the complexity of a Module Lightweight Design. Adapted treemaps were identified as a suitable tool. In the following, basics of Modularization and Lightweight Design are explained and the adapted treemaps for Module Lightweight Design are discussed and applied in an example.

DESIGN OF INNOVATIVE PRODUCT PROFILES: ANTICIPATORY ESTIMATION OF SUCCESS POTENTIAL

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According to the current trend to extend the domain of application of Engineering Design to the whole Product Cycle, i.e. from the definition of the product profile to the management of the dismantling procedures, the authors are investigating the possibility to define a practical toolkit to support the earliest stages of product development both in terms of prescriptions to generate new value propositions and assessment of the expected market appraisal. The present paper deals with the second objective and proposes a Value Assessment Metric (VAM) which allows to estimate the success potential of a new product through a balance of its functionalities and features with respect to the alternatives existing in the market. After reporting the methodological approach adopted to build the VAM, the paper presents its preliminary validation and an exemplary application to the proposition of an innovative lipstick.

DESIGN OF AN UPPER LIMB INDEPENDENCE SUPPORT DEVICE USING A PNEUMATIC CYLINDER

Saga, Norihiko; Kiriara, Koichi  
Kwansei Gakuin University, Japan

This paper describes a device to support a patient’s upper limb motion. For safety, light weight, and flexibility, it uses a pneumatic cylinder, for which the optimum arrangement is presented. The independence support device has two modes corresponding to livelihood support and rehabilitation contents. A compliance control system and a position control system are designed for those modes. We evaluate the effectiveness of the independence support mode through some experimentation.

ON THE DESIGN OF DEVICES FOR PEOPLE WITH TETRAPLEGIA

Gooch, Shayne (1); Medland, Tony (2); Rothwell, Alastair (3); Dunn, Jennifer (4); Falconer, Malcolm (1)  
1: University of Canterbury, New Zealand; 2: University of Bath, UK; 3: University of Otago, New Zealand; 4: Burwood Spinal Unit, New Zealand

People with complete tetraplegia are required to work at or near their physical limits in performing daily activities. Hence, subtle improvements to the design of assistive devices can have life changing consequences. This paper establishes a new procedure for characterizing the strength of people with tetraplegia. The data obtained along with the specifications of assistive devices are implemented in the Bath Constraint Modeller and then predictions made of a subjects ability to use the assistive device. This paper shows how improvements in wheelchair propulsion ability can be made within the constraints of normal wheelchair adjustment. From the characteristic strength maps produced in this study, it is predicted that more marked improvements can be obtained by changing the position of the applied propulsion force. The study proposes a new design concept involving an offset push rim which is expected to improve wheelchair propulsion ability for people with tetraplegia. More generally, the results of this study pose new opportunities for improvements to assistive devices for people while seated.

THE INVESTIGATION AND COMPUTER MODELLING OF HUMANS WITH DISABILITIES

Medland, Anthony John (1); Gooch, Shayne (2)  
1: University of Bath, United Kingdom; 2: University of Canterbury, New Zealand

Aids for the invalid or infirmed are often created simply by modifying those used by the able-bodied, with little care taken as to their individual needs and limitations. This study is aimed at determining their actual requirements through both modelling their anthropomorphic conditions, and measuring their physical capabilities. The subjects are evaluated in an experimental rig where, for example, the appropriate force data is collected. The physical limitations of the skeleton are also recorded and entered into a manikin model incorporated within a constraint environment. Together the manikin models are used to evaluate the disability aid under consideration. This approach has been employed in the study of wheelchairs for people with spinal injuries. Here the positions at which the maximum pushing capability of the subject can be determined and the chair modified, or redesigned, to allow this to be achieved. A similar approach can be applied to other invalid aids and medical equipment. A procedure is now being developed that can be applied to the collection of this data which can handle a range of problems for the creation of more effective aids for the elderly and infirmed.

A DESIGN METHODOLGY FOR HAPTIC DEVICES

Khan, Suleman; Andersson, Kjell  
Royal institute of Technology, Sweden

This paper presents a design methodology for optimal design of haptic devices, considering aspects form all involved engineering domains. The design methodology is based on parametric modeling, iterative and integrated design approach that leads to easier design space exploration for global optimal design and initial verification in the conceptual design phase. For global optimization, performance indices such as; workspace volume, isotropy, stiffness, inertia and control of the device were from all involved engineering domains were considered. To handle this complex and non-linear optimization problem, a multi-objective algorithm together with a new developed optimization function was used, to obtain a global optimum solution. A case study, where the methodology has been applied to develop a parallel haptic device is presented in detail in this paper. The results obtain from the test case model show significant improvements in the performances of the device.

SICK SYSTEMS: TOWARDS A GENERIC CONCEPTUAL REPRESENTATION OF HEALTHCARE SYSTEMS

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1: University of Cambridge, United Kingdom; 2: Loughborough University, United Kingdom; 3: Heart of England NHS Trust, United Kingdom; 4: Tricordant Limited, United Kingdom

In this paper, we argue that the healthcare systems within which patients are treated are like patients themselves. The systems display symptoms which may give indication of problems in an “organ” of the system. The human system that forms the core of healthcare activities is a complex system and so are healthcare systems. The success of medical diagnosis has been facilitated by a generic concept of the human anatomy and its systems, organs, and corresponding physiology. The lower levels are the building blocks on which the upper levels depend. Disease processes cause failure at the chemical levels and this failure affects organs, systems, and even the whole body. We observe an interesting similarity between the medical diagnosis process and the systems design approach, yet there is no corresponding generic representation of healthcare systems akin to the anatomy and physiology of the human system. Our goal in this paper is not to match the healthcare system to the human system part by part and organ to organ but to discuss how the structured medical diagnosis process can be applicable to healthcare systems if an appropriate conceptual representation of the system can be developed.

# Eliciting Customer and Stakeholder Requirements

Theme: Design Methods and Tools  
Chair: Boujut, Jean-François

## CLUSTERING CUSTOMER DREAMS – AN APPROACH FOR A MORE EFFICIENT REQUIREMENT ACQUISITION

Röder, Benjamin; Birkhofer, Herbert; Bohn, Andrea

Technische Universität Darmstadt, Germany

This paper introduces an approach for the acquisition of requirements centered on the idea of organizing requirements in requirement clusters. The acquisition of requirements is one of the first steps in the development process and is a key process for all following steps. The quality and quantity of the requirements acquired determine costs, necessary time and iterative steps needed in the whole development process. Due to the fact that the acquisition of requirements happens under vastly different circumstances in every project, the level of process standardization is very low. This low level of standardization results in a variety of problems: unnoticed implicit requirements, misunderstandings caused by non-standardized use of terms and incomplete or incorrect requirements. Clustering of requirements is a known concept, but up to now is used only after the process of acquisition to structure the requirements for further use. The use of requirement clusters in this paper aims at increasing the standardization and the quality by using requirement clusters in the process of requirement acquisition.

## A VALUE-CENTRIC QFD FOR ESTABLISHING REQUIREMENTS SPECIFICATION

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Quality function deployment (QFD) is commonly recognized as a tool or methodology for developing customer-focused products. There is, however, no explicit clarification about customer values in QFD. In the paper a value-centric QFD with qualitative and quantitative thinking of value is proposed for understanding customer needs and establishing requirements specification. The techniques of fundamental objectives hierarchy and means-ends objectives networks are utilized to structure reasonably the initially identified customer statements, which are possibly of different levels and granularities, and to uncover the implicit customer needs. Then quantitative analysis on value, e.g. value model and weight importance, is made possible by incorporating multi-attributes preference theory. It is believed that some underlying methodological problems in QFD can be interpreted and resolved in the value-centric framework. The business benefit of the value-centric QFD is that customer needs can be understood in terms of value and the design of alternatives is driven by their contribution to customer values.

## EVALUATING METHODS FOR PRODUCT VISION WITH CUSTOMERS’ INVOLVEMENT TO SUPPORT AGILE PROJECT MANAGEMENT

Benassi, João Luís Guilherme; Ferreira Junior, Lucelindo Dias; Amaral, Daniel Capaldo

University of Sao Paulo, Brazil

The literature from Project Management and Product Development areas relates the vision to the project development success. The agile project management relates the product vision to the project’s success too and, in addition, indicates the need to involve customers during this process. Would there be, therefore, methods to help achieve the two objectives during the planning of the project? The paper evaluated methods using an adaptation of the Repertory Grid Technique. The evaluation used constructs from literature of Product Development and Agile Project Management to assess the two aspects: support in building the vision and customer involvement. The results indicated that the methods do not achieve both objectives simultaneously, but on the other hand, have complementary profiles. This indicates that, theoretically, there is the possibility of associations in order to support the agile project management. Finally, the analysis of results also shows some suggestions of associations and possible adaptations of methods that need further study.

## USAGE CONTEXT-BASED CHOICE MODELING FOR HYBRID ELECTRIC VEHICLES

He, Lin; Chen, Wei

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Usage Context-Based Design (UCBD) has become an area of growing interest in engineering design research, due to the increasingly important role usage context plays in customers’ choices. In this paper, a usage context-based choice modeling framework (UCBCM) is presented to bridge the gap between engineering product design and customers’ choice of new products using hybrid electric vehicles (HEV) as an example. Uniquely, the product performances are explicitly modeled as a function of product design variables, customer profile, and usage context to reflect the heterogeneity in customer preference and usage context. Furthermore, the multinomial logic choice model is integrated with the ordered logit model to study the impact of vehicle design on consumer’s choice. The case study of HEV illustrates the usefulness of the UCBCM framework and demonstrates the importance of modeling usage context using both revealed preference data and consumer rating data.

# Evaluation Techniques

Theme: Human Behaviour in Design  
Chair: Andersen, Per Dannemand

## ON THE EFFECTIVE USE OF DESIGN-BY-ANALOGY: THE INFLUENCES OF ANALOGICAL DISTANCE AND COMMONNESS OF ANALOGOUS DESIGNS ON IDEATION PERFORMANCE

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Design-by-analogy is a powerful method for innovation, particularly during conceptual ideation, but also carries the risk of negative design outcomes (e.g., design fixation, risk aversion), depending on key properties of analogies used. This paper examines how variations in analogical distance, commonness, and representation modality influence the effects of analogies on conceptual ideation. Participants in this study generated ideas for an engineering design problem with or without analogous example designs drawn from the U.S. Patent database. Examples were crossed by analogical distance (near-field vs. far-field), commonness (more vs. less-common), and modality (picture vs. text). For comparison, a control group generated ideas without examples. Effects were examined on a mixture of ideation process and product variables. The results show positive effects of far-field and less-common examples for novelty and quality of ideas; also, the combination of far-field, less-common examples increased novelty relative to control. These findings suggest guidelines for the effective use of design-by-analogy, particularly a focus on far-field, less-common examples during conceptual ideation.

## CHOOSING INNOVATION: HOW REASONING AFFECTS DECISION ERRORS

Mounarath, Ronny; Lovallo, Dan; Dong, Andy

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Human beings are inherently fallible in their decision-making due to the constraints of bounded rationality. To make up for this inadequacy, we make judgments using a combination of deductive and inductive reasoning, which allows us to justify our decisions because we have implemented a process of proof. In this study, we conduct an experiment that simulates an uncertain environment characterized by incomplete information with members of a committee deciding whether or not to invest in innovation-oriented new product projects. We examine a third form of logic, abductive reasoning, and investigate the direction of its effect on the probability of project acceptance. We find that under abductive reasoning, individuals are more likely to accept projects. Our aim is not to show how to decide what is and what is not innovative, but rather to show that this decision is subject to the framing effects of logical forms of reasoning. The findings provide new psychological evidence on decision-making when choosing innovation, and raises questions on how juries choose innovative projects.

## A PROTOCOL FOR CONNECTIVE COMPLEXITY TRACKING IN THE ENGINEERING DESIGN PROCESS

Mathieson, James; Miller, Michael; Summers, Joshua

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The evaluation of design processes is often conducted after the process has been completed or as a case study on a single process. These two approaches each cannot be used to improve an ongoing process and require a great deal of time to generate statistically significant samples. Presented here is a protocol for tracking the interconnection of design process elements as a mixed temporal hypergraph network which may evolve in real time. The protocol uses email and limited human reporting data to develop the time-stamped connections of the network. At any time, this network or a filtered subset of it may be subjected to an analysis of graph and network properties. The response of these properties may then be correlated to either events or performance metrics. Here, this approach is applied to emails generated in the course of an undergraduate mechanical engineering senior design project. This application demonstrates an ability to identify deadlines, member roles, and work schedules from graph and network properties.

## APPLIED TESTS OF ENGINEERING DESIGN SKILLS:VISUAL THINKING CHARACTERIZATION, TEST

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A number of cognitive skills relevant to conceptual design have been previously identified. We have already reported on the contents, rationale and validation of divergent thinking test. This paper focuses similarly on the efforts related to the visual thinking and spatial reasoning in engineering context. It is designed to evaluate six measures: visual comprehension including perceptual speed, visual memory, visual synthesis mental image manipulation/ transformation, spatial reasoning and graphical expression/elaboration. We discuss the theoretical basis of a comprehensive test for engineers, test composition, trial runs and computation of reliability measures. The alpha version was given to a small set of subjects to determine clarity of the questions and gauge difficulty level. The beta version was used for norming and test validation from over 300 samples, engineering students and a smaller number of practicing engineers. The test is shown to be reliable (Cronbach alpha less than 0.05and only 2 eigenvalues greater than 1).



# Mechatronics Design

Theme: Design Processes  
Chair: Moehringer, Stefan

## DECISION BASED VARIABLE MECHATRONIC DESIGN PROCESSES

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1: Johannes Kepler University of Linz Austria; 2: HOERBIGER Automatisierungstechnik Holding GmbH Germany

Mechatronics design is integration of mechanics, electronics and software. As new functionality in products is realized to a large extent through integration of mechanics, electronics and software the need for knowledge integration between these disciplines becomes central. As a result both processes as well as the system modeling approach must support both the highly innovative functionality that are radically new for the organization as well the traditional features and models. Facing this challenge is the focus of this paper. After a brief wrap-up of recent concepts of innovation processes, the authors describe the specific characteristics of mechatronics design. Using the “degree of innovativeness” a key tailoring criterion, the authors will show how the existing and proven concept of idea management and innovation processes proposed by Thom as well as the staged-gate process proposed by Cooper have to be expanded to support mechatronic systems design and development. In the end, using this approach the development of a new product, an electrohydraulic compact axis, is briefly sketched within the context of the proposed process.

## A FRAMEWORK FOR INTEGRATED PROCESS MODELING AND PLANNING OF MECHATRONIC PRODUCTS

**Hellenbrand, David; Lindemann, Udo**

TU München, Germany

Mechatronic products are characterized by a high level of interdisciplinary and complexity in the technical system and its belonging development processes. In consequence this leads to novel requirements for process planning and the used methods and tools. The main challenge is to deal with the high complexity and a variety of interdependencies. Therefore a framework for integrated mechatronic process modeling and planning is presented. The focus is an effective integration of the involved disciplines mechanics, electronics and computer science into the overall development process. This leads to an improved synchronization of the single development processes and a common focus on the mechatronic system. The mechatronic development is seen as a system of interlinked cross domain processes and relations. It provides different and discipline independent views on the system in order to improve systems thinking. A Multiple-Domain-Matrix (MDM) approach is used to represent and analyze interdependencies within the product and the process. It allows for detailed analysis and deduction of implicit interconnections which can be regarded in the planning of the development process.

## A COMPARISON OF EVOLUTIONARY AND REVOLUTIONARY APPROACHES IN MECHATRONIC DESIGN

**Stetter, Ralf (1); Möhringer, Stefan (2); Pulm, Udo (3)**

1: Hochschule Ravensburg-Weingarten, Germany; 2: Simon Möhringer Anlagenbau GmbH, Germany; 3: BMW AG, Germany

Since ICED 2007 the special interest group (SIG) “mechatronics” is discussing research of mechatronic design. At the Design 2010 the findings were summarized to a research framework in order to support and give structure to further activities. During the numerous discussions the insight appeared that one of the most important characteristics is the starting point and the general procedure style of the strategies, methods and tools for mechatronic design, for instance the necessary amount of chaos. From an extreme point of view, one could identify two antagonistic concepts. A purely revolutionary approach will start from nothing but necessities of users or society and will follow a rigid procedure in order to design something totally new. On the contrary, a purely evolutionary approach will start with an existing product and will proceed in numerous cycles in order to design something better. Obviously, no black-and-white distinction of the existing approaches is possible or sensible. The ultimate goal of the ongoing research is the formulation of guidelines how a combination of both general directions could lead to more effective and robust mechatronic design processes.

## A MECHATRONIC CASE STUDY HIGHLIGHTING THE NEED FOR RE-THINKING THE DESIGN APPROACH

**Torry-Smith, Jonas Mørkeberg; Mortensen, Niels Henrik**

Technical University of Denmark, Denmark

Developing mechatronic products is a great challenge for many companies due to the multi-disciplinary nature of the development process. In this article the main objective is an investigation of seven aspects related to the synthesis process of developing mechatronic products. The role and effects of these aspects are illustrated by a case study. A literature study is performed regarding how well the seven aspects have been covered in the literature. It reveals that some suggestions for support can be found in terms of semi-formal modelling suggestions and proposal for procedures, but that the context of the proposed support often originates from a control engineering dominated research area. This circumstance leaves a vast amount of other types of mechatronic products with only sparse development support with the potential of being made operational.

# Design Curricula

Theme: Design Education  
Chair: Boelskifte, Per

## INTEGRATION OF DFMA THROUGHOUT AN ACADEMIC PRODUCT DESIGN AND DEVELOPMENT PROCESS SUPPORTED BY A PLM STRATEGY

**Ruiz Arenas, Santiago; Osorio Gómez, Gilberto**

EAFIT University, Colombia

In order to obtain an integral implementation of Design for Manufacture and Assembly-DFMA in a “Product Lifecycle Management –PLM” strategy, it is proposed a Product Design and Development Process-PDDP where the activities and tools of DFMA Methodologies are integrated through its different stages in a single and distributed way. This implies that DFMA will not be applied during the last stages of the process as a unique activity like it is proposed in most of the Product Design Methodologies, but it will be integrated more efficiently working from the first stages of the process. A first attempt oriented to the implementation of a holistic PLM strategy in a standardized academic PDDP adopted by the B.Eng. in Product Design Engineering is presented. This is an initial proposal to integrate DFX methodologies in this strategy, seeing that previous experiences have demonstrated that, at academic level, in projects where the application of all taught courses should be evident in the final designed product, students forget to apply considerations related to manufacturing and assembly issues.

## INTEGRATED SYSTEMS DESIGN EDUCATION

**Conway, Alastair; Wren, Graham; Ion, William**

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Integrated Systems Design refers to the design, development and integration of products and systems. Central to successful ISD is the co-ordination and incorporation of contributions from many professions and technologies. This presents challenges for organisations in the composition and supporting of integrated systems. One challenge is that many engineering graduates enter industry with little or no explicit knowledge of ISD and systems thinking. This in turn results in reduced organisational efficiency and increased post employment training. The hypothesis is simple; provide engineering students with ISD principles and you will provide organisations with graduates who can contribute to industry quicker. The Royal Academy of Engineering appointed a Visiting Professor at the University of Strathclyde, with the overall aim to produce a pilot scheme integrating systems design education into engineering programmes. This paper charts the key project findings, beginning with a review of ISD practice within industry and academia. From this review, an analysis matrix was developed and piloted allowing Universities to analyse the extent ISD is being taught and identify gaps in knowledge.

## DO BASIC SCHEMATA FACILITATE EMBODIMENT DESIGN?

**Z avbi, Roman (1); Fain, Nusa (1); Rihtarsic, Janez (1,2)**

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There is a positive correlation between the number of generated alternative product concepts and their quality. Many different approaches/methods/tools have been developed to facilitate synthesis of alternative product concepts based on variations of physical laws, material, geometry and geometrical position. One of such tools is SoPHY (Synthesis of PHYsical laws), which is based on chaining of physical laws and complementary basic schemata. An experiment was designed, which is the first in series of experiments which are planned to assess various aspects of the use of the method/computer tool. The assumption tested in the experiment was that basic schemata generated by the computer tool (automatic phase) offered appropriate guidance for generating alternative embodiments due to more focused approach (manual phase). The presentation of the experiment and its results are the focus of the paper.

## A COHERENT AND DISCRIMINATING SKILLS STANDARD FOR INNOVATIVE DESIGN

**Choulier, Denis; Weite, Pierre-Alain**

UTBM (Belfort-Montbéliard Technology University), France

We introduced a skills and capabilities standard into two teaching modules at XX university. Four skills were defined from knowledge of the design activity, from which 32 capabilities were derived. The modules deal mainly with functional analysis and TRIZ tools for technical problems solving, but the relative proportion of TRIZ differ, as well as student's backgrounds in design. Students were asked to evaluate each of their own capabilities. This set of capabilities was easy to understand by students. The scattering seems contained, and comparisons between the series of data show differences between capabilities, skills, populations of students, and modules contents. The results show that a learning session can make students more aware of their (average) initial level and also reveal overestimated as well as non recognised initial capabilities. Moreover, all the differences we observed can be explained by the modules or students features such as students' backgrounds or amount of teaching relating to a given skill. This skills and capabilities standard therefore appears coherent and discriminating, and its use in academic and industrial context can be programmed.

CONSIDERATION OF GOAL INTERRELATIONS IN LIFECYCLE-ORIENTED PRODUCT PLANNING

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Within the innovation process the phase of product planning plays an important role in order to deduce consistent product disposals to be developed and produced by the company. Demands and corresponding product goals as well as trends concerning future solutions have to be anticipated and systematically analysed and opposed in order to place products accepted by customers and at the same time deliverable by the company. Thereby, early identification of goal interrelations and goal conflicts which arise by applying certain product concepts is essential. This paper therefore provides a graph- and matrix-based approach by considering product functions to link product goals among each other via possible solutions and respective characterising parameters. The approach focuses further on an integrated lifecycle perspective in order to consider company, market and environmental demands and potentials from the phases of developing and producing until the phases of using and disposing products.

ANALYSIS OF CREATED REPRESENTATIONS OF THE DESIGN OBJECT DURING THE PROBLEM SOLVING PROCESS

Albers, Albert; Wiedner, Aaron

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During the process of developing new solutions, the designer creates different representations of the design object, which have a high variation in their level of abstraction. These representations have great impact on reaching the project targets. Therefore, it is important to understand how the designers create these representations for the problem solving, in order to derive general ways of proceeding. This paper describes the assessment, classification and analysis of designer's proceedings during the process of problem-solving, based on two examples from the industry. The evaluation contains the created representations, as well as the proceedings for the problem solving. The results show, what level of detail and what scope is to be preferred by the designer, for representing the design object during the different stages of the problem solving. Furthermore, it is shown, in what order problems are solved during the design process.

DESIGN PROCESS AUTOMATION – A STRUCTURED PRODUCT DESCRIPTION BY PROPERTIES AND DEVELOPMENT OF OPTIMIZATION ALGORITHMS

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Automation of the product development process or of sub-processes is one possibility to support designers by their daily work. A concept for a formalized and structured description of profile-structures (assemblies of bifurcated sheet metal profiles) by properties is needed as basis for designing and optimizing them automatically. The high object complexity requires dividing profile-structures into defined design elements. The inputs of an algorithmbased design process are on the one hand the target properties and the relations between the properties. Furthermore rules, principles and guidelines of embodiment design as well as restrictions of manufacturing have to be transformed and included in an automated design process. The algorithms are the key elements of the chosen approach. A developed algorithm to design welded connections between linear flow split profiles proves that the independent properties of this design element can be determined automatically and the design can be optimized.

USING SIMULATION TO SUPPORT PROCESS INTEGRATION AND AUTOMATION OF THE EARLY STAGES OF AEROSPACE DESIGN

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Computer-aided engineering (CAE) software tools for design representation, analysis and optimization play a central role in aerospace engineering. Increasingly these tools are being integrated to automate data transfer, thereby reducing design cycle times and increasing the power of design search and optimization techniques. The majority of work concerning process integration and design automation has focused on the technical issues involved in improving the capability and interoperability of design tools and the means of incorporating them into automated workflows. Of lesser concern has been assessing the performance of these workflows prior to implementation. This paper reports on research at Rolls-Royce that used process mapping and discrete event simulation to help design and predict the performance of an automated design system that is being developed for the early stages of civil aero engine design. The findings of this research are that process simulation can add value to mapping the design process by quantifying the expected outcomes of different implementation scenarios and, thereby, indicating opportunities for further process improvements.

INTEGRATED PROCESS AND PRODUCT MODEL FOR THE EVLAUATION OF PRODUCT PROPERTIES

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Friedrich Alexander Universität Erlangen Nürnberg, Germany

Providing the right product information at the right time is an important factor for an efficient product development process and especially for the evaluation of product properties. But due to the mass of different documents and types of data representing product information and the highly dynamic and iterative processes a rigidly or statically linkage between all product and process information is almost impossible. Therefore a dynamic and generic linkage between product and process information is necessary to efficiently support the data logistic within the product development process and to safeguard the steady evaluation of product properties. This approach links product and process information as models within a semantic web. By the additional consideration of the employed tools and methods a quantifiable representation of the information flow within companies can be accomplished. The analysis of this information flow should support the project manager in planning which properties can be evaluated during the product development process with which tools or methods. Moreover a prediction of the quality of this evaluation and of the dependent product information is possible.

ITEM LIFE CYCLES IN PRODUCT DATA MANAGEMENT: A CASE STUDY ON HOW TO IMPLEMENT A DESIGN DATA VALIDATION PROCESS

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1: CERN, Switzerland; 2: MedAustron, Austria; 3: G-SCOP, France

At the start of a new design project, product data management (PDM) system is one of the first to be implemented. Soon the design has to be shared, released or approved, either for prototyping or manufacturing, and the PDM system has to fulfil the not always explicit requirements of the users. This paper describes what has to be implemented at the early stage of a new design project in order to get an actual use of PDM. It is based on a real case study in 2010 for a new project in a new organisational structure, with new tools and new processes applying to new team members. The process of implementing and using a PDM system is described, covering not only the classical title blocks for 2D drawings, but the release of 3D models and the relationship with the item approval. The proposed item-centric approach helps the designers, engineers and managers to make a proper distinction between the life cycle of the item and the life cycles of the CAD-entities that describe it, to assign the adequate status to these entities, depending on their maturity level, and to build up a common shared representation.

# Emotion

Theme: Human Behaviour in Design  
Chair: Badke-Schaub, Petra

## CHALLENGES AND LIMITATIONS OF APPLYING AN EMOTION-DRIVEN DESIGN APPROACH ON ELDERLY USERS

**Andersen, Casper L.; Gudmundsson, Hjalte P.; Achiche, Sofiane; Boelskifte, Per**

*Technical University of Denmark, Denmark*

Population ageing is without parallel in human history and the twenty-first century will witness even more rapid ageing than did the century just past. Understanding the user needs of the elderly and how to design better products for this segment of the population is crucial, as it can offer a competitive advantage for companies. In this paper, challenges of applying an emotion-driven design approach applied on elderly people, in order to identify their user needs towards walking frames, are discussed. The discussion will be based on the experiences and results obtained from the case study. To measure the emotional responses of the elderly, a questionnaire was designed and adapted from P.M.A. Desmet’s product-emotion measurement instrument: PrEmo. During the case study it was observed that there were several challenges when carrying out the user survey, and that those challenges particularly related to the participants’ age and cognitive abilities. The challenges encountered are discussed and guidelines on what should be taken into account to facilitate an emotion-driven design approach for elderly people are proposed.

## EMOTION-DRIVEN ELICITATION OF ELDERLY PEOPLE USER NEEDS ILLUSTRATED BY A WALKING FRAME CASE STUDY

**Gudmundsson, Hjalte P.; Andersen, Casper L.; Achiche, Sofiane; Boelskifte, Per**

*Technical University of Denmark, Denmark*

In this paper an emotion-driven design approach is used to elicit the needs of elderly users illustrated by a walking frame case study. First, images of existing walking frames were collected from websites and clustered into categories, followed by a collection and an assessment of the emotional responses of elderly people presented with the representative walking frames from each category, using a questionnaire adapted from the Product measurement instrument (PrEmo). The results of this assessment were categorized using three levels of product emotions (visceral, behavioural and reflective) and then transformed into user needs that can be later used by designers to create new designs. From these user needs it was found that the elderly had concerns with emotional content as well as more traditional needs based upon ergonomics and functions.

## INGREDIENTS OF THE DESIGN PROCESS: GOING THROUGH EMOTIONAL PASSAGE

**Shin, Cliff**

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Conventional design processes have been successful the past decades. As our society becomes faster and more complicated, so customers’ needs are becoming more complex. Discovering insights about those customers has been challenges because consumers want products that are more than just pretty objects. This paper will present a design research method, “Emotional Passage” as a way to access customers’ real emotions and thoughts. The Emotional passage process for design consists of pain diagnosing, metaphor elicitation, proper questioning, and face studying. The paper will explore each component and discuss the reasons behind each component. The paper will illustrate how important emotions are in the design. Also, this paper will present how to implement each component to the different stages in real projects or the classrooms.

## A SOUND-BASED PROTOCOL TO STUDY THE EMOTIONS ELICITED BY PRODUCT APPEARANCE

**LU, Weihua; PETIOT, Jef**

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Emotions influence how a customer interacts with the product. To be able to instill emotional value in product design, the understanding of user emotion and the measure of emotions are interesting challenges. Several measuring methods use visual stimuli as assessment scale. Until recently, hearing was an ill-explored part for emotion measurement. This paper describes a new protocol based on sounds for eliciting user emotion. The method uses a set of sounds and association tests, made by a panel of participants. The same objects, cars pictures, were evaluated by two user-tests based on both this new protocol and a classical protocol, the Semantic Differential. We describe in the paper the main stages of the new method, and we compare the results with the Semantic Differential Method using Principal Component Analysis and Generalized Procrustes Analysis. The new protocol seems to be a useful means to collect the intuitive emotion of users

## EMOTIONAL ORIENTATION AND CONTEXT ANALYSIS FOR DESIGN CREATIVITY EXERCISE TEST

**Shin, JongHo; Kim, Yong Se**

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An exercise program addressing cognitive elements of creativity was devised so that personalized needs in specific elements could be addressed. The exercise program provides users with an opportunity to enhance the creativity in a personalized adaptive manner with regard to five cognitive elements: fluency, flexibility, originality, elaboration and problem sensitivity. Dynamically changing affective states are considered related to contexts in the program and an affective modeling was presented in this regard. The effectiveness of the exercise program was evaluated by using conceptual design tasks, in the form of pre-test and post-test. It was reported, 70% of students achieved enhance in design creativity. Further mining on the log data indicate the enhanced design creativity is reversely associated with negative affective states. In addition, a framework of processing natural language was introduced for estimating emotional orientation from text. It was observed that emotional orientations tend to be context-dependent and the positive emotional orientation appears when users achieve enhance in design creativity. The framework promises its application to affective modeling.

## CULTURAL “VALUE CREATION” IN THE DESIGN OF CELLULAR PHONES

**Liem, Andre; Aryana, Bijan**

*Norwegian University of Science and Technology, Norway*

The extension of Cagan and Vogel’s “Value Creation Model” with culture as an additional component may enhance the search for superior value and competitive advantage. However, to manage different judgments and positioning of different evaluators, contextual research on users is needed in order to find more valid classifications. It is important to understand how users consider each of these dimensions when they want to define an identity for a product. As a case, cellular phones were used for discussing cultural factors as well as relationships among values, lifestyles and consumer behaviour. With respect to individual features and components, no specific design recommendation can be made at this point of time. Attribute based methods were not enough for understanding users’ real behaviour and tendencies towards a product. A product is more than just a combination of its components or attributes. However, a more elaborate mapping of hardware and software components onto Hofstede’s cultural dimensions can lead to interesting findings based on the identification of cultural specific components, especially when comparing between Asian and Western likings and requirements.



WANTS CHAIN ANALYSIS: HUMAN-CENTERED METHOD FOR ANALYZING AND DESIGNING SOCIAL SYSTEMS

Maeno, Takashi; Makino, Yurie; Shirasaka, Seiko; Makino, Yasutoshi; Kim, Sun

Keio University, Japan

In the present paper, WCA (Wants Chain Analysis) is proposed by extending CVCA (Customer Value Chain Analysis). CVCA is a method for visualizing relationship among stakeholders for analyzing existing social systems and designing new social systems. WCA is a method for visualizing wants and needs of stakeholders in CVCA. In WCA it is shown that people’s wants or needs are finally realized through the looped and linear chain of relationship among stakeholders. With various examples, effectiveness of WCA is shown by describing that characteristics of business/social system structure can be clearly visualized using WCA. It is described that WCA is useful when it is used for analyzing existing systems as well as creating new systems. It is also shown that “think of others” should be more and more important for humans’ satisfaction and happiness in the near future. WCA can be a tool for clarifying what is for others.

THE USE OF STORYBOARD TO CAPTURE EXPERIENCES

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Today, product realization is becoming more squeezed in time and the need to capture experience from previous projects is an important factor for being successful in developing new products and services. This paper aims to investigate the use of storyboard to highlight earlier experiences from a narrative theory perspective and in relation to contemporary cognitive theories regarding how external representations facilitate collaborative work. This paper will discuss and come up with suggestions as to why storyboard can be a supportive method through the use of narrative theories. One of the objectives of the actual research project is to assist industry in developing strategies and methods to capture “lessons learned” in previous projects and use earlier experiences to avoid repeating mistakes. This will then release working capacity to be used for creativity and innovations instead. The conclusion of the paper presents storyboard as a supportive method for capturing earlier experience from a product realization project. It also argues that it is valid to borrow the concept focalizer from narrative theory.

DESIGNING TO MAXIMIZE VALUE FOR MULTIPLE STAKEHOLDERS: A CHALLENGE TO MED-TECH INNOVATION

Aquino Shluzas, Lauren M.; Steinert, Martin; Leifer, Larry J.

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An inductive, multi-case analysis was conducted to examine how design practices involving physicians and medical device developers influence outcomes in early stage medical device companies. This research was motivated by an interest in understanding the role of users in the device development process, specifically in terms of how user interaction influences the acceptance or rejection of new products. An analytic framework for case-based research was first developed, followed by eight retrospective case studies on entrepreneurial firms. Based on a mixed-methods analysis, the study showed that product adoption relied on maximizing benefits for product stakeholders, while minimizing required changes in physician behavior. The data further illustrated that total benefit to product stakeholders was influenced to the greatest degree by benefits afforded to hospitals and physicians, assuming patient benefit was greater than or equal to the standard of care. This study highlights the importance of identifying the often-conflicting needs of medical device stakeholders, and then optimizing devices to satisfy the needs of those with the greatest influence over product use and adoption.

CUSTOMER VALUE IS NOT A NUMBER – INVESTIGATING THE VALUE CONCEPT IN LEAN PRODUCT DEVELOPMENT

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1: Norwegian University of Science and Technology, Norway; 2: Stanford University, USA

Lean Product Development (LPD) is an operational philosophy aimed at maximizing customer value while minimizing non-value-added-activities, known as waste. Originating from manufacturing, the value-concept in Lean is still strongly tied to product features despite evidence that perceived value concerns more than just the physical product. This paper presents different views on customer value, as provided by the employees at a Norwegian boat manufacturer, customers, and the competition. Our research suggests that a less-than-perfect match between customer needs and product offerings may prove beneficial. Furthermore, how customers perceive product value depends on previous experience. It is also suggested that deep understanding of customer-defined value does not imply an ability to satisfy that value. A purchasing decision often relies on emotional and utilitarian value, and product developers must target both. Yet, the value-concepts used in LPD tend to revolve around utilitarian value alone. An extension of LPD towards Lean Innovation (LI) is suggested.

A METHODOLOGY FOR DESIGNING A RECOMMENDER SYSTEM BASED ON CUSTOMER PREFERENCES

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This paper presents a contribution to design an online preference based system. The objective of the system is to assist a customer in the products selection process. Current e-commerce recommendation systems assist customers in this process. Nevertheless, quality of the recommendations produced remains a real challenge. There are products that are by mistake recommended to customers and inversely. This paper focuses on these quality and relevance of recommendations. More than product objective characteristics, the customer's choice is also based on his/her perceptive expectations. Therefore, to be considered as relevant, products recommendations must reach customer’s expectations and particularly perceptive ones, sometimes spontaneously, without specific request. Collaborative filtering and neighbourhood formation are the main tools used. The cluster of “perceptive” neighbours containing the active customer share common perceptive preferences and can guide the propositions. The application case is the comic. The aim is to propose to a customer a “good” product. A test procedure enabling the validation of this algorithm is to be set.

DESIGN PREFERENCE ELICITATION: EXPLORATION AND LEARNING

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We study design preference elicitation, namely discovery of an individual’s design preferences, through human-computer interactions. In each interaction, the computer presents a set of designs to the human subject who is then asked to pick preferred designs from the set. The computer learns from this feedback in a cumulative fashion and creates new sets of designs to query the subject. Under the hypothesis that human responses are deterministic, we investigate two interaction algorithms, namely, evolutionary and statistical learning-based, for converging the elicitation process to near-optimally preferred designs. We apply the process to visual preferences for three-dimensional automobile exterior shapes. Evolutionary methods can be useful for design exploration, but learning-based methods have a stronger theoretical foundation and are more successful in eliciting subject preferences efficiently.

# Function and Performance Modelling

Theme: Design Methods and Tools  
Chair: Wallace, Ken

## EXPLORING POTENTIALS FOR CONSERVATIONAL REASONING USING TOPOLOGIC RULES OF FUNCTION STRUCTURE GRAPHS

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This paper explores the possibility of supporting automated function-based reasoning in the conceptual design phase, specifically, reasoning needed to perform physics-based concept validation. Eleven atomic tasks of topologic reasoning, divided in two categories, connectedness and derivation, are identified that could be used to check graph-based function structures against conservation laws using only the count and types of flows attached to the functions. This reasoning is illustrated by simulating the sequential actions of a designer developing a new mechanical device. Next, recently proposed formal definitions of function verbs are used to explore the possibility of supporting additional quantitative reasoning toward conservational concept validation. Finally, these findings are used to identify information elements that must be captured in a formal representation of mechanical functions in order to support this reasoning.

## ON THE FUNCTIONS OF PRODUCTS

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Understanding the performance and manner of functioning of existing products is at the base of new product development activities. In engineering design the term function is generally used to refer to the technical actions performed by a product. However, products accomplish a wider range of goals. This research has explored the opportunity to describe and model, through the concept of function, product actions across four dimensions including technical, aesthetic, social and economic. The research has demonstrated that non-technical functions can be represented through active verbs and nouns and modelled using a method known as the Function Analysis Diagram (FAD). The research argues that when technical, aesthetic, social and economic perspectives on product development are considered as different types of function, stakeholders have a common language to communicate which can benefit design collaboration.

## PROPOSAL ABOUT THE USE OF DATA BASE IN ENGINEERING DESIGN

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Design can be defined as the human activity aimed to conceive and develop the “best” constructive solution, capable to perform a given function. In this paper we will present the conception of a data base capable to archive constructive solutions related to a given function: such a data-base can become the starting point of the design process and a useful tool for the designer. The structure of this data-base has been conceived starting from the schema of the design process, in order to store a functional model derived from several functional representations available in the technical literature.

## SEVEN YEARS OF PRODUCT DEVELOPMENT IN INDUSTRY – EXPERIENCES AND REQUIREMENTS FOR SUPPORTING ENGINEERING DESIGN WITH ‘THINKING TOOLS’

Matthiesen, Sven

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At the centre of the present contribution is the part of the engineering design process in which the embodiment design is created. On the basis of the author's experiences in industrial engineering design and the management of engineering design projects and engineering design teams the attempt is made to describe the creative engineering design process and thus make it more vivid.

The function is in the centre of company’s interest because cost-effective fulfilment of function is the main selling criterion of any product.

It is shown how function arises in the interaction of several components of a product and in their interaction with the product’s environment.

Engineering design is the pre-thinking of and documenting of an “embodiment” which is established to enable the function of the product. This process will then be described. On that base possibilities and requirements for academic research for promoting these activities are shown.

After that, industrial experiences will be described which were gained in working closely with the Contact&Channel-Model. It will be shown that “thinking tools” can help to support the processes necessary for creating a new product.

# Design for Modularity

Theme: Design for X, Design to X  
Chair: Nielsen, Ole Fiil

## IMPACT OF MODULARISED PRODUCTION ON PRODUCT DESIGN IN AUTOMOTIVE INDUSTRY

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1: Daimler AG, Germany; 2: Karlsruhe Institute of Technology, Germany

During the last decades, the product life cycle in the automotive industry decreased from 10 to 6 years or even less. At the same time the demand for individualized and configurable cars has increased. This has led to new challenges in product development and production planning. One key factor in order to gain important time and cost potentials in the different project phases is a standardised production.

This contribution deals with the influences of a standardised and modularised production on the product design and presents the most important requirements and restrictions which have to be taken into account already in an early phase of the development process. Furthermore, a new approach is introduced which supports the designer in consideration of this requirements and influences the product design from a production point of view. Afterwards the introduced methodology is demonstrated with the help of a body-in-white welding cell. Finally this contribution ends with a summary and a short outlook towards future activities.

## A NEW APPROACH TO MODULARITY IN PRODUCT DEVELOPMENT – UTILISING ASSEMBLY SEQUENCE KNOWLEDGE

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1: M3M Laboratory UTBM / MABl, France; 2: DDMEM University of Strathclyde, Scotland; 3: M3M Laboratory UTBM, France; 4: LIFC Laboratory IUT Belfort-Montbéliard, France

This article describes an approach dedicated to routine design of “highly productive” modular product ranges incorporating principles of functional analysis, Design For Assembly (DFA), and techniques from modelling and simulation of multi-physics applied to parametric CAD models. The paper focuses on techniques of assembly sequence generation based on modules identified, and module parameters identification and rule generation. This methodology entitled Functional And Robust Design (FARD) aims to take into account the modularity of product ranges while considering DFA constraints. It takes into consideration of the functions of a product and its assembly constraints in the early stages of the design process simultaneously. An experimental case study on a pneumatic scraper is presented to illustrate the effectiveness of the methodology. This paper focuses on the functional design and the DFA part of the proposed methodology.

## PRODUCT AND PROCESS EVALUATION IN THE CONTEXT OF MODULARIZATION FOR ASSEMBLY

Halfmann, Niklas; Elstner, Steffen; Krause, Dieter

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The determination of modular product structures requires a continuous evaluation of the measures taken. Modularization is an appropriate method for product structuring. It provides the opportunity of taking into account the requirements from different product life phases, such as the development, production or after-sales phase. The assembly, as an essential part of the production for the company, demands easy mountable products. Short lead times and flexible processes are the main requirements among others. The methodical procedure presented in this paper proposes the integrative representation of the product structure and its resulting assembly sequence in a single diagram. The developed tool provides the opportunity to perform structuring measures to the product and coincidentally show the impact on the assembly process. For the evaluation the use of key figures is proposed. The relevant input for the calculation of these key figures is similarly extracted from the diagram. Conclusively, the procedure is applied to an example of aircraft interior development.

## APPROACH TO VISUALIZE THE SUPPLY CHAIN COMPLEXITY INDUCED BY PRODUCT VARIETY

Brosch, Max; Beckmann, Gregor; Krause, Dieter

Hamburg University of Technology, Germany

Due to the high level of individualization and globalization, companies increase their product variety, which leads to an increased internal complexity at the level of the products, business processes and the SC.

The Institute of Product Development and Mechanical Engineering Design (PKT) has developed the Integrated PKT approach for developing modular product families, to reduce the internal variety with methods, that are aiming to handle, to reduce and to avoid complexity. To extend this approach to the level of the supply chain, the method Deign for Supply Chain Requirements is under development. The important first step is to ascertain and to visualize the supply chain complexity induced by product variety. An approach to realize this first step is presented in this paper.

# Functional Reasoning II

Theme: Design Theory and Research Methodology  
Chair: Vermaas, Pieter

## A THEORY OF DECOMPOSITION IN SYSTEM ARCHITECTING

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The divide-and-conquer principle is a technique to deal with large-scale problems by dividing them into smaller and manageable problems. In engineering design, the principle is often used not just as a complexity management method but also as an embodiment method, although its formalization is unclear if not non-existing. This paper attempts to formalize the principle in the context of design of complex multi-disciplinary systems such as mechatronics systems. It proposes a theory of decomposition in conceptual design (system architecting), which extends the decomposition theory in traditional engineering design based on functional decomposition. The theory is applicable to system decomposition processes, in which building blocks necessary for decomposition are not available or must be newly designed during the processes. The theory uses parameter relations governed by physical phenomena realizing functions. A case study of system architecting of a printer is illustrated as a demonstration of the theory.

## DO FUNCTIONS EXIST?

**Fantoni, Gualtiero; Apreda, Riccardo; Gabelloni, Donata; Bonaccorsi, Andrea**

University of Pisa, Italy

The paper proposes a model where functions are not considered as primitive objects in themselves but rather as a complex network of relationships between different, more fundamental entities. Exploring the connections between goals, behaviors, operations, etc. at various levels has several advantages. It allows integrating in a unique framework different approaches to design, from the FBS model to Functional Basis one and provides tools for a more powerful analysis. The new picture can also help modeling affordances, misuses, redundant functions, failures and so on. The representation of the relationships between functions, user’s goals and expectations, behaviours and physical features in the case study of a common glass shows how the model can help designing better products, and at the same time illustrates the various critical issues in the model itself and suggests possible directions of investigation.

## ON THE LINK BETWEEN FEATURES AND FUNCTIONS

**Gabelloni, Donata; Apreda, Riccardo; Fantoni, Gualtiero**

University of Pisa, Italy

A critical issue in design theory is the relationship between the abstract functions and purposes of a product and its physical behaviours, structures and features. In the traditional approach systematized by Pahl and Beitz, the main focus is on the functions, seen as actions on flows. While such paradigm proved very useful and has been tested in many practical cases, it shows various limits when dealing with not purely mechanical artefacts, since it overlooks the role of structures and the relationship between the user and the product. On the other hand, there is a family of theoretical frameworks (e.g. Gero’s FBS) that inserts the concept of function in a wider and more sophisticated picture, including the physical features, the designer’s intentions and the user’s perceptions and actions. However those models are often studied only theoretically and present practical cases in short examples, just to illustrate the theory. Such practical applications would also help to resolve ambiguities, clarify the understanding of problematic issues, and even suggest new directions of analysis. The present paper is an attempt to build a bridge between the two approaches.

## COURSES OF PRODUCT DEVELOPMENT IDENTIFICATION – EFFECTS AND VISIONS

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University of Belgrade, Serbia, Republic of

It is a paradox that wide and intensive activities in the field of product development and design in the course of more than 30 years has produced situation that existing consensus about the lack of new products. The article joins efforts to discover the reasons for this situation and to establish methodology for prediction courses of product development based on TRIZ methodology. The first part of the article contains an analysis of product development and design efforts in the past time in connection with social and economic circumstances, discoveries and important inventions. The trends of actual product development and design methodology are also analyzed. The second part of this work attempts to identify main postulates, potentials and forces which cause product development expansion. In the past a few of those factors and their results have been identified. For the future, new power sources based on atomic fusion and the nanotechnologies are identified as the main “motors” for locomotion of evolutionary or revolutionary product development.

# Structuring Information and Knowledge Modules

Theme: Design Information and Knowledge  
Chair: Liu, Ying

## UNDERSTANDING ENGINEERING SYSTEMS THROUGH THE ENGINEERING KNOWLEDGE GENOME: STRUCTURAL GENES OF SYSTEMS TOPOLOGIES

**Shai, Offer; Reich, Yoram**

Tel Aviv University, Israel

The design of contemporary products requires knowledge from diverse disciplines. Presently, there is very little common denominator among engineering disciplines. This state of affairs is hurting practice, potentially leading to failures. Similar to the knowledge genome in biology, we briefly present the concept of the Interdisciplinary Engineering Knowledge Genome (IEKG) as a foundation for integrating engineering disciplines. We review the concepts of sysyetrn and method genes and present a new type of gene – structural system gene – that serves as a building block from which well-constrained systems in diverse disciplines could be constructed. We illustrate how these genes are used in analysis and sythesis in several disciplines. Each of these illustrations is a contribution in its own right in the particular discipline, yet they are derived from the same genes. These results demonstrate the power of the IEKG, as a theoretical construct, to engineering design. Further benefits could be obtained by incorporating additional disciplines into the IEKG, discovery of new genes, and enrichment of systems and method genes in a bootstrapping fashion.

## DEVELOPMENT OF ENGINEERING KNOWLEDGE MODELS TO ACHIEVE PRODUCT INNOVATION

**Karlsson, Anna (1,2); Torlind, Peter (1)**

1: Sandvik Coromant, Sweden; 2: Luleå University of Technology

To pursue understanding of governing principles, observations of phenomena and simulation of processes instead of relying purely on trial-and-error, is becoming more and more important in product development activities. This suggests that use of engineering knowledge models is an important part of future innovations. The purpose of this study is therefore to gain insight into the development and use of engineering knowledge models in the innovation process. Based on interviews with originators of such models within a manufacturing company this descriptive study emphasizes the following aspects: the ambivalent aspect of reuse, multi-use of existing models and increased interactivity provided by engineering knowledge models.

## REFERENCE MODEL FOR TRACEABILITY RECORDS IMPLEMENTATION IN ENGINEERING DESIGN ENVIRONMENT

**Š torga, Mario (1); Marjanović, Dorian (1); Savšek, Tomaž (2)**

1: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia, Republic of; 2: TPV d.d., Novo mesto, Slovenia

The work reported here builds on the framework for engineering information development traceability by discussing the traceability records implementation within engineering environment. The four key processes in the product development practice (requirement-, change-, characteristic-, and decision management) have been considered in more details as a basis for the development of the traceability reference model. Reference model for traceability records represents dynamic container of the traceability elements, information and links semantically enriched in order to provide the context of the information objects development. Two case studies for preliminary evaluation of the presented approach have been shortly discussed. The further steps in TRENIN ([www.trening.org](http://www.trening.org)) project progression have been identified and described.

## A STRUCTURE FOR REPRESENTING PROBLEM FORMULATION IN DESIGN

**Dinar, Mahmoud; Shah, Jami J.; Langley, Pat; Hunt, Glen R.; Campana, Ellen**

Arizona State University, United States of America

Much study has been done on the process of design and problem formulation is believed to play a major role in a creative design of high quality. Yet, it has gained less attention. We propose a taxonomy for representing the design problem space in order to show how a problem is formulated. We call this static representation the problem map which can provide a basis for comparing how different designers perceive a problem. It can also help demonstrate the co-evolution of problem and solution. Our study is based on the design of a model aircraft by an expert and a group of novice designers. The proposed structure shows a richer map of attended attributes and relations for the expert and more attributes left in vacuum for the novices.



	D	Discussion Sessions				P	Podium Sessions				W	Workshop Sessions		
08:30 - 10:00		<div>Strategies for Sustainability</div> <div>p108</div> <div>Room: Discussion Room 1</div> <div>Theme: Design for X, Design to X</div> <div>Global Educational Perspectives</div> <div>p110</div> <div>Room: Discussion Room 2</div> <div>Theme: Design Education</div> <div>Mechatronic Systems</div> <div>p112</div> <div>Room: Discussion Room 5</div> <div>Theme: Product and Systems Design</div>					<div>Value Creation through User Orientation</div> <div>p114</div> <div>Room: Podium Room s01</div> <div>Theme: Design Organisation &amp; Management</div> <div>Introducing New Products and Technologies</div> <div>p115</div> <div>Room: Podium Room s09</div> <div>Theme: Design Methods and Tools</div> <div>Design Process Performance</div> <div>p116</div> <div>Room: Podium Room s02-03</div> <div>Theme: Design Processes</div> <div>Rationale</div> <div>p117</div> <div>Room: Podium Room s10-11</div> <div>Theme: Design Information and Knowledge</div>					<div>Human Behaviour SIG Workshop: Design Communication</div> <div>p105</div> <div>Room: Workshop Room s08</div> <div>Computational Design Synthesis SIG Workshop: The Challenge</div> <div>p106</div> <div>Room: Workshop Room s16</div> <div>Emotional Engineering SIG Workshop: Emotions and Expectations</div> <div>p107</div> <div>Room: Workshop Room s06</div>		
10:00 - 10:30	Break													
10:30 - 11:50		<div>Process Oriented Methods</div> <div>p118</div> <div>Room: Discussion Room 1</div> <div>Theme: Design Processes</div> <div>User Input</div> <div>p120</div> <div>Room: Discussion Room 2</div> <div>Theme: Human Behaviour in Design</div> <div>Knowledge Transfer and Reuse</div> <div>p122</div> <div>Room: Discussion Room 5</div> <div>Theme: Design Information and Knowledge</div> <div>Design Research Methodology</div> <div>p124</div> <div>Room: Podium Room s01</div> <div>Theme: Theory and Research Methodology</div> <div>Managing Product Failure and Uncertainties</div> <div>p125</div> <div>Room: Podium Room s09</div> <div>Theme: Design Methods and Tools</div> <div>Methods and Tools for Sustainable Design I</div> <div>p126</div> <div>Room: Podium Room s02-03</div> <div>Theme: Design for X, Design to X</div> <div>Shaping the Engineering Designer</div> <div>p127</div> <div>Room: Podium Room s10-11</div> <div>Theme: Design Education</div>					<div>Human Behaviour SIG Workshop: Design Communication</div> <div>p105</div> <div>Room: Workshop Room s08</div> <div>Computational Design Synthesis SIG Workshop: The Challenge</div> <div>p106</div> <div>Room: Workshop Room s16</div> <div>Emotional Engineering SIG Workshop: Emotions and Expectations</div> <div>p107</div> <div>Room: Workshop Room s06</div>							
12:00 - 12:30	<div>Automotive Keynote: Innovation and Entrepreneurship</div> <div>Hasse Johansson, Vinnova</div> <div>Main Hall</div> <div>p128</div>													
12:30 - 13:00	<div>Mechatronics Keynote: Arduino &amp; RepRap - Creating Wealth by Giving it Away</div> <div>Adrian Bowyer (University of Bath) &amp; David Cuartielles (Malmö University)</div> <div>Main Hall</div> <div>p129</div>													
13:00 - 14:15	<div>Lunch</div> <div>Functional Descriptions</div> <div>Room: Workshop Room s08</div> <div>Decision Making SIG</div> <div>Room: Workshop Room s16</div> <div>Collaborative Design</div> <div>Room: Workshop Room s04-05</div> <div>JED Editorial Meeting</div> <div>Room: Workshop Room s06</div> <div>p81</div>													
14:15 - 15:45		<div>Design Theory Debate</div> <div>p130</div> <div>Room: Discussion Room 1</div> <div>Theme: Theory and Research Methodology</div> <div>Risk-Management in NPD</div> <div>p132</div> <div>Room: Discussion Room 2</div> <div>Theme: Design Organisation &amp; Management</div> <div>Manufacturing and Design Information</div> <div>p134</div> <div>Room: Discussion Room 5</div> <div>Theme: Design Information and Knowledge</div> <div>Decision Making Processes</div> <div>p136</div> <div>Room: Podium Room s01</div> <div>Theme: Design Processes</div> <div>Managing Design Changes and Alternatives</div> <div>p137</div> <div>Room: Podium Room s09</div> <div>Theme: Design Methods and Tools</div> <div>Managing Complex Systems</div> <div>p138</div> <div>Room: Podium Room s02-03</div> <div>Theme: Product and Systems Design</div> <div>Teams</div> <div>p139</div> <div>Room: Podium Room s10-11</div> <div>Theme: Human Behaviour in Design</div>												
15:45 - 16:00	Break													
16:00 - 17:15	<div>Design Society General Meeting</div> <div>Main Hall</div> <div>p140</div>													
18:30 - 19:30	<div>Boat trips</div> <div>Nyhavn</div> <div>p141</div>													
19:30 - 23:00	<div>Gala Dinner</div> <div>Langelinie Pavillon</div> <div>p141</div>													

DESIGN COMMUNICATION

Chairs: Maaike Kleinsmann (TU-Delft), Anja Maier (DTU) & Petra Badke-Schaub (TU-Delft)

About the workshop

Background - Information exchange is one of the most relevant activities in almost each working environment and it is an ever increasing issue in design. Often however, research on design communication seems to focus on two or three parameters only which are then ‘proven’ to be of importance for the design team(s) as the result is shown as ‘successful’ or ‘unsuccessful’. How do the chosen parameters relate to others not chosen? Of course, the amount of parameters which may influence the process and quality of communication is gigantic and associations between them are manifold and often hard to comprehend. How can we arrive at a sound overview of relevant parameters and interconnections which influence successful design communication? Workshop discussions can probably make a start towards answering such a question.

Aim

The aim of this workshop is to explore parameters that characterise the field of Design Communication now and in the future, and discuss the impact of our research on society.

Programme outline

The workshop emphasises three main topics within the broad field of design communication. For each topic, a plenum discussion is followed by two invited presentations (ca. 5 minutes) with different and potentially opposing perspectives and propositions. The dialectic format of the workshop shall encourage to actively engage in discussion. The chair person will ensure a summary of the discussed parameters at the end of the discussion of the specific topic. It would be very valuable if we arrive at the end of the workshop with a meaningful composition of relevant parameters that characterise Design Communication and their influences on the design process.

- Introduction: Design Communication as essential field within Human Behaviour in Design
- Topic 1: Processing design information at interfaces in networks
  - Plenum discussion on human interfaces in design and the need for potentially different ways of communication
  - Presentation and discussion of two invited papers
  - Summary
- Topic 2: Representations/models/objects as design communication
  - Plenum discussion on representations and their influence on design communication
  - Presentation and discussion of two invited papers
  - Summary
- Topic 3: Methods and tools supporting communication and the design process
  - Plenum discussion on how to support the designer with methods and tools in order to improve design communication
  - Presentation and discussion of two invited papers
  - Summary
- Overall summary and conclusion: Generated knowledge on what characterises Design Communication, the research field’s impact on society, and future aims of the HBiD SIG

THE COMPUTATIONAL DESIGN SYNTHESIS CHALLENGE

Chairs: Iestyn Jowers (TU München) and Kristina Shea (TU München)

About the workshop

This workshop will show, tell and discuss the current state-of-art, limitations and key challenges in computational design synthesis (CDS). One particular challenge identified at a workshop in 2010 is that the field needs benchmark, or challenge, problems to be able to compare research methods and implementations, identify beneficial uses for CDS as well as high-potential application domains.

The workshop will present a culmination of research efforts on newly developed challenge problems established at the CDS Summer School at TU München in August 2011. Due to the wide variety of representations and application domains in CDS, these include a topology optimisation problem, a spatial synthesis problem and a functional synthesis problem. Researchers from around the world are attending this summer school prior to ICED and will be applying their own research methods and implementations to produce the best results. In the workshop at ICED, the results for the benchmark problems will be presented to foster discussion on the problems themselves and the latest methods.

The organisers will coordinate a focused discussion around the following research questions:

- Is it possible to develop a set of universal benchmark problems for CDS?
- How and where is knowledge encoded in different CDS methods?
- How can we develop “best-practice” guidelines for modeling synthesis problems and required knowledge?
- How can we evaluate and compare results for benchmark problems? Can we produce “human-competitive” results?
- How can CDS methods be integrated in design practice and with current design toolsets?

Workshop format

The Workshop will start with an introduction from the chair, which will include a summary of the outcome of the CDS summer school, and an overview of the research questions that will be explored during the workshop. This will be followed by short presentations from invited participants. The workshop will then split into smaller groups, each of which will explore a specific research question in detail. Results from these discussions will be reported back to the workshop and summarised.

All ICED participants are welcome to join!

EMOTIONS AND EXPECTATIONS

Chairs: Shuichi Fukuda (Stanford University)

Agenda

To cope with the diversification and needs for personalization, the importance of emotion in creating values in the products and in the processes are quickly increasing. This SIG will share the status quo of the participating countries and will discuss the future directions of how emotion can be introduced in the whole product life cycle from design, manufacture and use. We hope to clarify how design should be changed to meet this goal.

The workshop will consist of discussions around the operations of SIG, including:

- Web seminar
- Local meetings
- International meetings

Focus

The importance of emotion in creating values in the products and in the processes are quickly increasing. We hope to clarify how design should be changed to meet this goal.

Speakers

- Prof.Udo Lindemann, Technical University of Munchen, “User Expectation versus Product Service Systems”
- Assistant Prof. Hideyoshi Yanagisawa, University of Tokyo, “Deviation of Sensory Experience from its Prior Expectation (Potential of Expectation Effect in Emotional Quality)”
- Consulting Professor Shuichi Fukuda, Stanford University, “Emotion and Expectation Management in Engineering”

DEVELOPING AN ECOLOGY OF MIND IN DESIGN

Dewberry, Emma Louise

Open University, United Kingdom

The relationship between design and sustainability (DfS) is forever evolving: from the early focus on cleaner production processes and resource efficiencies to more recent endeavours to promote environmentally benign behaviours or to counter the increasing impacts of climate change. The uncomfortable truth though is that the majority of design activity serves market forces at a global scale and at an ever-increasing rate. Despite predictions of resource scarcity – peak oil, peak minerals, peak water – the increase in the linear transit of material through the Global economy rises year on year. Design straddles this production consumption cycle: it conceives of the processes and technologies that shape our artificial world; and it fashions the forms of that artificial world that drive a consumption ideology. Neither position is sustainable. Informed by Sterling’s rigorous exploration of different sustainable education paradigms, this paper reconstructs a design literacy that has the capacity to realize effective transitions for the long-term wellbeing of environment, biodiversity and humankind.

ECODESIGN IN INDUSTRIAL DESIGN CONSULTANCIES – COMPARING AUSTRALIA, CHINA, GERMANY AND THE USA

Behrisch, Johannes Christoph (1); Ramirez, Mariano (2); Giurco, Damien (1)

1: University of Technology, Sydney, Australia; 2: University of New South Wales

This paper presents the results of an empirical study, investigating the uptake of ecodesign by industrial design consultancies (ID consultancies) in Australia, China, Germany and the USA. There still appears to be no widespread uptake of ecodesign into product development praxis by industrial designers, with most ecodesign activity focusing on the engineering phase. Especially seldom are the necessary radical interventions to significantly improve the environmental performance of products. The literature review revealed that ID consultancies might be in a position to improve this situation. This paper presents the findings of a website content analysis, investigating the extent of ecodesign uptake by ID consultancies in Australia, China, Germany and the US. The paper verifies that ID consultancies have a high potential to improve ecodesign uptake by using their influence especially on early phases of the product development process and by addressing also non engineering related issues for ecodesign. This potential does not appear to be fully embraced yet.

GETTING TO SUSTAIN (-ABLE SYSTEMS) VIA USING SURVIVABLE AND IMPOSE-ABLE ONES

Greene, Richard Tabor

KEIO University, Japan

A question posted to MIT alumni on Linkedin attracted responses by 371 engineers about what their engineering education lacked. Part of that data presented a crowd-sourced new theory of sustainable systems, presented in this paper--showing design for surviving, and design for imposing being later used as opportunities for design for sustainability. Survivable systems, impossible systems are defined, and ways to empower engineers to equal or surpass the power of MBA managers later in their careers, suggested by the 371 respondents are presented.

INTEGRATION OF REMANUFACTURING ISSUES INTO THE DESIGN PROCESS

Hatcher, Gillian D; Ijomah, Winifred L; Windmill, James F C

University of Strathclyde, United Kingdom

Remanufacturing is the process of returning a used product to like-new condition with a warranty to match. The efficiency and effectiveness of this process greatly depends upon product design; there are certain product properties that may have a positive or negative effect on steps of the remanufacturing process. The concept of ‘design for remanufacture’ or ‘DfRem’ is a design task dedicated to improving the remanufacturability of a product. However, it would appear that very few products are currently designed for remanufacture and the reasons behind this have yet to be fully explored. This paper provides an overview of the problem and a discussion of some of the preliminary findings of a study aimed at improving designers’ ability to carry out DfRem. The findings provide an early indication of some of the factors affecting the integration of DfRem into the design process.

REFLECTIONS ON DESIGN FOR SUSTAINABILITY- A VIEW FROM A DISTINCT POINT AND THE ROLE OF INTERIOR DESIGNER

Kazamia, Kika Ioannou (1); Gwilliam, Julie (2)

1: University of Nicosia, Cyprus; 2: University of Cardiff

This paper explores the term “Interior Design” and in particular the relationship of the interior design profession with its direct and indirect impacts on the environment. Through a brief analysis, we explore this close relationship, establishing opportunities designers have to promote environmental sustainability. This work goes on to elucidate the role of the interior designer in the delivery of sustainability, providing examples from literature. Further, the process of design, within a context of sustainability is examined, from the design purpose, source of inspiration and subject through to the selection of materials, method of construction and finally, the realization of the idea. Finally, the paper expands the relationship of the interior design profession to the wider scope of social and economic sustainability and suggests a strategy which leads to the involvement of community to promote the uptake of sustainability. In summary, this paper presents an example of an innovative approach to interior design practice, working towards the promotion of holistic sustainable practice

MANAGEMENT OF ENERGY RELATED KNOWLEDGE IN INTEGRATED PRODUCT DEVELOPMENT -- CONCEPT AND SELECTED INSTRUMENTS

Götze, Uwe (1); Leidich, Erhard (2); Bierer, Annett (1); Koehler, Susann (1)

1: Chemnitz University of Technology, Germany; 2: Chemnitz University of Technology, Germany

Beside functionality, cost, quality, and so on, design engineers are facing a new challenge – the development of energy efficient products. Since especially in the early phases only few solid knowledge about the impacts of design alternatives on energy related figures like consumption, savings, or efficiency is available, the need for a systematic management of energy related knowledge is evident. For this purpose and on the basis of an integrated product development framework, the paper emphasizes the variety of energy related knowledge in product development, presents a concept for an energy related knowledge management and exemplifies its systematic identification, use, and development with help of development-concurrent energy calculations and a target energy management approach.



IMPROVING ENGINEERING EDUCATION IN INDIA USING INFORMATION AND COMMUNICATION TECHNOLOGY: A NEW FRAMEWORK

Mehta, Prerak Prakashchandra

Industrial Design Centre, Indian Institute of Technology Bombay, India

Given the current scenario of engineering education in India, there is a dire need of improvement in the way engineering education is structured and the guidelines it follows. With Information and Communication Technology (ICT) having become accessible and widespread, it is bound to play a vital role in enhancing the state of engineering education. The existing structure and framework of engineering education and its surrounding ecosystem have been studied in great depth. The paper proposes a new framework for engineering education using ICT. A generic level component breakup for engineering will be made, followed by detailed description of each component, again on a generic level. Each detailed description has been followed by ways of executing them based on different branches of engineering. The entire engineering education scene needs to move towards a self-learning environment which is totally lacking in today's faculty dependent model. The new framework components along with the guidelines will pave the way for a self-learning environment based model for engineering education. It will be a founding stone for ICT based initiatives in engineering education in India.

LEARNING LEVELS IN TECHNICAL DRAWING EDUCATION: PROPOSAL FOR AN ASSESSMENT GRID BASED ON THE EUROPEAN QUALIFICATIONS FRAMEWORK (EQF)

Metraglia, Riccardo; Baronio, Gabriele; Villa, Valerio

Università degli Studi di Brescia, Italy - Faculty of Engineering

For several years the European Commission for Education and Training has been trying to build a translation device to make comparable national qualifications, aiming to promote workers and learners' mobility within EU and to facilitate their lifelong learning. A basis to achieve this goal is to use common assessment grids to certify skills and abilities. The abilities in Technical Drawing seen as a working tool and as a language of communication, despite the existence of a certification, the ECDL-CAD, for the ability to use the computer to draw, are not assessed. This paper highlights the consequences of the lack of certification of skills in Technical Drawing, with particular reference to the authors' experiences in corporate and academic fields. Then, the paper introduces a proposal for an assessment grid for the evaluation of Technical Drawing learning levels, based on the European Qualifications Framework (EQF), with separate learning outcomes for knowledge, skills and competences. Finally, it's shown an example of Europass Certificate Supplement, with reference to the proposed grid, to certify the learning outcomes of a Technical Drawing course taught in our Faculty.

STRENGTHENING ASIAN ADVANCED DESIGN AND MANUFACTURE EDUCATION THROUGH A FRAMEWORK APPROACH

Rehman, Fayyaz (1); Yan, Xiu-Tian (2); Li, Youhua (2); Tan, Xincai (2); Miller, Eric (1); Woodfine, Nick (1)

1: Southampton Solent University, Southampton, UK, United Kingdom; 2: Strathclyde University, Glasgow, UK, United Kingdom

The rapid industrial growth of some Asian countries demands to bridge the gap between Europe and Asia for mutual sharing and exchange of knowledge and cooperation in Advanced Design and Manufacture. A European Commission funded project provided a new platform for not only strengthening Asian education in design and manufacture but also helped in creating strong ties between European and Asian academic institutions for exchange and sharing of knowledge through joint course material development, delivery of MSc course in advanced design and manufacture and joint supervision of PhD training of Asian students. This paper introduces the project, key activities implemented during its duration, achievements and the impact it had regarding the introduction of world class engineering design and manufacture education in Asia through the up gradation of knowledge and skills of postgraduate Asian students. The project's implementation also built strong partnerships between European academic institutions and Asian industrial sector as well as laying foundations for the development of numerous research and education based projects between Asian and European academic and industrial sectors.

MEASURING MALAYSIAN UNDERGRADUATE SKILLS IN READING AND INTERPRETING ENGINEERING DRAWING

Burvill, Colin Reginald (1); Field, Bruce William (2); Abdullah, Zulkeflee (1)

1: The University of Melbourne, Australia; 2: Monash University, Australia

Following a survey of representatives from Malaysian manufacturing industry that identified concerns over engineering graduates' abilities to properly interpret professional manufacturing drawings, a systematic study of relevant undergraduate abilities was initiated. A composite assembly/dimensioned drawing was selected to form the basis of a test that could be presented to students in engineering courses at the Universiti Teknikal Malaysia Melaka. 232 engineering undergraduates at all four levels were tested. The distribution of overall scores from the test fell within the planned range, with some students performing considerably better than others, indicating that the test would be suitable for further use as a pre- and post-test for follow-up investigations of methods for increasing graduate skills. However, student responses for some of the questions were noticeably poor, against initial expectations. A deeper analysis of those questions revealed that respondents required not only an ability to interpret the information presented on the drawing, but an understanding of the engineering technology contained in the drawn artifact.

NEW JOB ROLES IN GLOBAL ENGINEERING – FROM EDUCATION TO INDUSTRIAL DEPLOYMENT

Lindow, Kai (1); Müller, Patrick (2); Stark, Rainer (1,2)

1: Technische Universität Berlin, Germany; 2: Fraunhofer-Institute of Production Systems and Design Technology

Product creation is facing the next level of fundamental changes. Global demands are growing substantially to achieve energy efficient and sustainable value creation networks for production, products and services without compromising traditional success factors such as time to market, cost and quality. Competition in engineering design is characterized by actors and stakeholders such as designers, engineers, OEMs, suppliers, or engineering service providers, by technical targets and economic factors within the field of application. To face such challenges, new roles in engineering design have to be implemented in organizations and development projects. Otherwise, new engineering design methods will lack deployment in industrial practice and finally fail. This paper addresses the need for selected new engineering job roles to deploy former made achievements in engineering design. The focused roles are "PSS Architect", "Sustainability Mentor", and "Virtual Product Creation Engineer". Within the contribution requirements on teaching and the industrial deployment of the new job roles in a global engineering environment are presented.

IDENTIFYING AND QUANTIFYING INDUSTRY PERCEPTIONS OF ENGINEERING DRAWING SKILLS IN NOVICE MALAYSIAN ENGINEERS

Burvill, Colin Reginald (1); Field, Bruce William (2); Abdullah, Zulkeflee (1)

1: The University of Melbourne, Australia; 2: Monash University, Australia

This paper reports on a survey completed to investigate the engineering drawing based technical competencies of novice (graduate) engineers from the perspective of the manufacturing industry sector. The survey sought the views of engineering managers about both the competencies of current novice engineers and their expected competency for effectiveness within their workplace. The survey quantified anecdotal information provided by Malaysian colleagues. Survey questions were based on interviews with experienced Malaysian design and manufacturing engineers. 150 Malaysian industries were invited to participate in the online survey, of which 35 industries participated. The survey revealed that for all twelve issues investigated, there was a management perception that novice engineers have a lower competence than is management's expectation for the ability of current novice engineers. The survey participants identified the visualization of the three dimensional (3D) form of an object based on two dimensional (2D) drawing(s), and the interpretation of 2D drawings with interconnected parts as the competencies needing the most improvement in novice engineers.

## ANALYZING THE DYNAMIC BEHAVIOR OF MECHATRONIC SYSTEMS WITHIN THE CONCEPTUAL DESIGN

**Bauer, Frank; Anacker, Harald; Gaukstern, Tobias; Gausemeier, Jürgen; Just, Viktor**

*Heinz Nixdorf Insitut, Germany*

The increasing penetration of mechanical engineering by information technology enables considerable benefits. This is expressed by the term mechatronics, which means the close interaction of mechanics, electric/electronics, control and software engineering to improve the behavior of a technical system. The development of such systems is complex. Consequently a domain-spanning specification is required, which describes the system in total and builds the basis for all further communication and cooperation between the experts from the involved domains in the concretization. In order to validate the system, different tests are accomplished during the concretization phase. In this contribution we present how dynamics analysis may be integrated already in the conceptual design phase. For this purpose a simulation tool is used for the validation of the dynamic behavior of the system already on the basis of the principle solution. The refinements effected during the simulation are transferred back into the principle solution. This improves the provided information for the following domain-specific concretization.

## PRODUCT DEVELOPMENT SUPPORT FOR COMPLEX MECHATRONIC SYSTEM ENGINEERING–CASE FUSION REACTOR MAINTENANCE

**Leino, Simo-Pekka Sakari (1); Mäkinen, Harri (1); Uuttu, Olli (2); Järvenpää, Jorma (1)**

*1: VTT Technical Research Centre of Finland, Finland; 2: Eurostep Oy, Finland*

Development of a multidisciplinary mechatronic system, like a remote operated maintenance system of ITER fusion reactor, requires system engineering approach. System engineering is leadership approach for designing totally new concepts and technology. On the other hand, system engineering needs support for managing all related processes and information. Product lifecycle management (PLM) can be seen as IT-aided enabler of such processes and information management desires. Divertor Test Platform 2 (DTP2) is a full scale mock-up and test facility for developing, testing and demonstrating remote operated maintenance equipment as well as planning and training future maintenance operations. Characteristic for DTP2 is that its development and operational lifecycle will be several decades long. History of the system has to be traceable and all data must be available during the whole lifecycle. This work in progress paper aims to introduce the first results of the ongoing project, which defines and implements PLM support for DTP2 system engineering. The preliminary results include requirements specification for the PLM platforms, and a concept for mechatronic product model and data model.

## DESIGNING MECHATRONIC SYSTEMS: A MODEL-INTEGRATION APPROACH

**Qamar, Ahsan (1); Wikander, Jan (1); During, Carl (2)**

*1: KTH-Royal Institute of Technology, Sweden; 2: Micronic Laser Systems, Sweden*

Development of mechatronic products demands different types of design models in order to support both domain-independent specifications and domain-specific principles. This research aims to find out how system-level modeling can support mechatronic design, and how the integration of system-level modeling and domain specific modeling can be supported during different design phases. An integrated modeling and design infrastructure is proposed to support abstraction between mechatronic design models, hence supporting co-evolution of design models. The paper concludes that a mechatronic design problem can be better supported through such an integrated design approach. However, usability of this approach needs to be further supported by more case studies in the future. An active hospital bed wheel module design example is presented to show firstly the relationship between conceptual design and system-level modeling, and secondly the need for integration of system level and domain specific design models.

## INTERDISCIPLINARY SYSTEM MODEL FOR AGENT-SUPPORTED MECHATRONIC DESIGN

**Stetter, Ralf (1); Seemüller, Holger (1); Chami, Mohammad (1); Voos, Holger (2)**

*1: Hochschule Ravensburg-Weingarten, Germany; 2: Université du Luxembourg, Luxembourg*

Today mechatronic design usually suffers from a lack of domain-spanning IT-support. Commonly, each discipline is using its specific IT-tools and data formats and the abundance of logical connections between the disciplines is only present in the designer's minds or in unstructured documents such as MS Word or MS PowerPoint files. Many approaches to unify the tools and data during the last two decades were made but have not made their way into the product development departments in industrial practice. One approach to document and use the connections between the disciplines are agent based systems. Such systems use independent software entities representing either components of the product to be developed or certain process segments which interact in a system called agent system. Due to their flexibility and the ability to achieve solutions which satisfy multiple objectives such systems are a promising approach to address the challenges of mechatronic design. However, the application of such systems requires the documentation of the interdisciplinary connections in an interdisciplinary system model. In this paper SysML is proposed for this specific task and is applied to a product.

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DTU

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- Production and organisation development

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Otherwise see [www.man.dtu.dk](http://www.man.dtu.dk)





# Value Creation through User Orientation

Theme: Design Organisation and Management  
Chair: de Vere, Ian James

## EXPANDING THE SOCIAL DIMENSION: TOWARDS A KNOWLEDGE BASE FOR PRODUCT-SERVICE INNOVATION

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The extension of businesses to incorporate the provision of function as a service in supplement to standalone products is an ongoing movement in manufacturing industry. In short, this means that the development intent should be guided by the need of ‘performance in use’ that the customer wants, e.g. thrust rather than an engine. By this, the established knowledge base challenges the development team.

This paper embarks from the assumption that there are three main challenges, i.e. (1) radical innovation activities, (2) customer data acquisition and (3) the transformation of data into design information. The purpose is to discuss knowledge sharing activities to contribute to radical innovation for Product-Service Systems (PSS). In this study it has been found that contemporary activities filter out tacit dimensions of knowledge. Therefore, a meeting format for transferring tacit knowledge to support building a knowledge base for innovative work is proposed.

## RETHINKING VALUE: A VALUE-CENTRIC MODEL OF PRODUCT, SERVICE AND BUSINESS DEVELOPMENT

**Randmaa, Merili (1); Mouggaard, Krestine (2); Howard, Thomas James (2); McAloone, Tim C. (2)**

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Globalization and information technologies have made the economical landscape more transparent and customers smarter, more demanding and networked. Companies can see these changes as a threat to their business or as an opportunity to differentiate in the market and be a Prime Mover, by re-thinking customer value within the value system. This article shows how the term “value” is understood in different contexts and fields of economy, to see if these definitions can be merged, in order to understand the concept of value in broader way. The authors argue through literature review and example cases that seeing value from multi-disciplinary viewpoint opens up some unused opportunities for the companies to overcome barriers within a value system, design integrated products and services, work more effectively, co-create value with customers, make use of word-of-mouth promotion and achieve long-term relationships with customers. A new concept for re-thinking the \_value system\_ is proposed and its main potentials to improve firms’ performance are described.

## OVERCOMING THE KEEP THE MARKET OUT PREMISE (KMOP) IN PRODUCT DEVELOPMENT

**Lang, Alexander (1); Kirschner, Rafael (2); Kain, Andreas (2); Lindemann, Udo (2)**

1: IMAN Solutions GmbH, Germany; 2: Technical University Munich (TUM)

Even though market research methods including Open Innovation tools and techniques have improved, most companies have not managed to decrease their flop rate of newly developed products in recent years. As customers we all recognize B2C products, which might mainly have that problem, but flop rates which do not decrease also count for companies, which are active on B2B and B2C markets. For the market information collected, here referred to as market intelligence, it seems to be difficult to move through the organization from the collector – mainly the marketing department – to the R&D department, where developers should use the information in order to develop products, the market is waiting for. What mechanism or tool could this “Keeping the market out premise – Kmop” under which the R&D departments of most companies still develop product help to overcome? Through a qualitative study – focusing on market pull – within 5 internationally operating German companies between 2008 and 2010, the aspects of Kmop were identified, clustered in focus areas and a first concept to overcome the barrier between Market Intelligence and Product Development is proposed.

## EFFECTIVE SCHEDULING OF USER INPUT DURING THE DESIGN PROCESS

**Choi, Young Mi**

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User input is a critical component to any product design project. Product design approaches and methods provide proven frameworks for utilizing input once it has been collected. However, these frameworks do not provide any formal mechanisms for scheduling user engagements during the course of design. This paper investigates a method based on the Design Structure Matrix which might be used to effectively schedule user engagement through the example of the design of an assistive technology product.

# Introducing New Products and Technologies

Theme: Design Methods and Tools  
Chair: Kim, Yong Se

## SIGNIFICANCE OF REQUIREMENTS FOR THE IMPLEMENTATION OF NEW TECHNOLOGIES USING SHAPE MEMORY TECHNOLOGY

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In this paper the assumption of a conflict between existing requirements and the application of new technologies will be illustrated by using examples based on shape memory technology. For this purpose, two product concepts are analyzed. Starting with the planning phase and the definition of system requirements, the described design processes also include conceptual, embodiment and detail design phases. Special attention is paid to the specification of requirements and their effect on the respective product concept. The aim of this paper is to identify influences on the product concept caused by the conflict between existing requirements and the application of new technologies. Certain requirements, e.g. historically based requirements, prevent the application of those new technologies in many cases. Therefore, the application of new technologies in combination with established requirements is investigated and then re-evaluated after the adaption of critical requirements.

## ON THE TYPES AND ROLES OF DEMONSTRATORS FOR DESIGNING MEDICAL DEVICES

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Unlike many fields that make the most of advances in numerical modeling and simulation, actors involved in medical technologies R&D have more and more recourse to demonstrators when designing a product. These concrete materializations are a handy support at certain stages, but an inadequate use of mock-ups and prototypes can lead to tackling the problem in a roundabout way, at the risk of ending with an unsuitable product that does not meet the users’ needs. Based on our own experience in research projects in close collaboration with clinicians, this paper tries to sort out the different types and characteristics of demonstrators, regarding their potential uses at the successive stages of the design process. The general discussion is clarified by several illustrative examples that underline the important roles demonstrators play to help designers finding the right way on the winding path towards an innovative and useful medical device.

## A MORPHOLOGICAL APPROACH TO BUSINESS MODEL CREATION USING CASE-BASED REASONING

**Lee, Ji Hwan; Hong, Yoo S.**

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This study aims to provide a structured methodology for a business model creation. Based on a morphological analysis of business model, we propose the methodological chart named as business model creation template with which one can generate a variety of business model alternatives. The template consists of a set of predefined building blocks which describes the strategic patterns and/or constituent elements of a business model. Those building blocks have been collected and verified through comprehensive analysis of real-world business model cases and relevant literature. Furthermore, we develop case-based reasoning system for supporting a new business model creation. The system aims to provide the business model planner of intuitive cases in creating a new business model. Based on a case base that contains about a hundred of real business models, the system receives an input query from a business model planner, and retrieves similar cases to the query based on case matching mechanism. In the case study, we actually generate the new business model alternatives for apparel company that want to commercialize their newly designed product.

## USE OF DESIGN METHODOLOGY TO ACCELERATE THE DEVELOPMENT AND MARKET INTRODUCTION OF NEW LIGHTWEIGHT STEEL PROFILES

**Nehuis, Frank; Ziebart, Jan Robert; Stechert, Carsten; Vietor, Thomas**

TU Braunschweig, Germany

In the transportation sector –as in most other branches– demanded time-to-market becomes shorter whereas at the same time demanded diversity becomes wider and lightweight requirements become tougher. For this reason the project "Development of a highly integrated modular profile family for the automotive and transportation sector from high and ultrahigh-strength steels with stress-matched sheet thickness gradients" (HIPAT) was established. The project aims to accelerate the development and market introduction of new lightweight rolled steel profiles. As means to achieve this aim a special design catalogue with HIPAT components, design tools and design rules pertaining to lightweight constructions and the integration of functions was developed and combined to create a continuous design methodology. This design methodology is distinguished mainly by its applicability in early design phases.



ENSURING THE INTEGRATION OF PERFORMANCE AND QUALITY STANDARDS IN DESIGN  
PROCESS MANAGEMENT: CODESTEER METHODOLOGY

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The current competitive environment urges all companies to launch actions striving to improve their activities, in regards to products, processes, or organizational aspects. But how to intervene? What are the measures which will optimize in the best way the system performance ? Parallels, with the aim of a better global efficiency, indicators and dashboard are fulfilled and monitored within robust Quality management system, which allow better steering the company's interests regarding objectives. But are they well adapted and well integrated regarding the need of the design activities? In order to set the basis of a framework, we present, in this paper a state of the art of what we call “performance” and “quality” in design. We look at the stakes of coupling the 2 concepts and the limits of the existing models. We therefore strive to present the Codesteer methodology, describing the static model and a dynamic loop to implement it. The last part of our article presents a software application of CodeSteer and its roll out on academic design cases.

KPI MEASUREMENT IN ENGINEERING DESIGN – A CASE STUDY

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This paper proposes that standard Key Performance Indicators (KPIs) for project management are appropriate for measuring and monitoring Engineering Design Processes. A case study was performed to study which KPIs can be used and how they need to be changed to fit specific ED projects, The study was performed at a global power generation equipment manufacturer during a period of 15 months in three locations. The most important objective of the project was to develop a KPI reporting concept covering the design process in order to implement an interactive Management KPI Dashboard. The case study supports the view that standard project management KPIs can be used with some customizations specific to the nature and size of the company, the projects and the project teams

BAYESIAN PROJECT MONITORING

**Matthews, Peter C; Philip, Alex D M**

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This paper studies how subtle signals that can be observed from the execution order of a project with several tasks can be used to diagnose potential problems that will hinder the project. Specifically, by representing the workflow of the project as a Markov Chain and observing how long the project takes to arrive at its first gateway, it is possible to infer the nature of any potential problems with the project. This diagnosis is achieved through using Bayesian methods, and provides a ranked list of potential problems, along with the probability for each problem. Two examples are used to illustrate how this approach works.

RULES FOR IMPLEMENTATING DYNAMIC CHANGES IN DSM-BASED PLANS

**Karniel, Arie; Reich, Yoram**

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Planning a New Product Development (NPD) process has an evolving nature. It is repeatedly updated during the development due to changes in requirements, technology, product concept, or testing results that drive product design modification and require changes in the plan. The Design Structure Matrix (DSM) is utilized to generate a process plan that is based on the product knowledge. The translation of the DSM-based plan to a process scheme requires implementation rules. Such translation is not unique and there are implementation choices we define as business rules. This paper presents the implementation rules used for dynamic changes in the plan. The application of these rules conforms to a correctness criteria based on the soundness criteria used in Petri nets.

THE RETRIEVAL OF STRUCTURED DESIGN KNOWLEDGE

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Design rationale is an effective way of capturing knowledge. It is generally captured by identifying elements and their dependencies, i.e. in a structured way. Current retrieval methods focus mainly on either the classification of rationale or on keyword-based searches of records. Most of the current keyword-based retrieval methods discard the implicit structures of these records, resulting either in poor precision of retrieval or in isolated pieces of information that are difficult to understand. This ongoing research aims to go beyond keyword-based retrieval by developing methods and tools to facilitate the provision of useful design knowledge in new design projects. Specifically, methods for utilising various structured information are developed and implemented on a prototype keyword-based retrieval system developed in our earlier work. The implementation and evaluation of these methods shows that the structured information can be utilised in a number of ways, such as filtering the results and providing more complete information. This allows the retrieval system to present results that are easy to understand, and which closely match designers’ queries.

EXPLOITING NEIGHBORHOOD AND MULTI-DIMENSION GRANULAR INFORMATION FOR  
SUPPORTING DESIGN RATIONALE RETRIEVAL

**Liu, Ying**

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Based on our previously proposed ISAL model (issue, solution and artifact layer) for design rationale (DR) representation, in this paper, we report our efforts in researching a ISAL based DR retrieval framework to better support DR retrieval by taking advantage of neighborhood and multi-dimension granular information presented in DRs. In our proposal, DR is firstly extracted and indexed using ISAL and a document profile model respectively. Next, an initial DR graph is formed by linking up different DRs based on their document citations and document similarities. A DR network is therefore established by integrating similarities from issues, solutions and artifact aspects using neighborhood information in the DR graph. In order to prioritize DRs retrieved, a graph-based ranking approach is further engaged. To validate the approach proposed, we have reported our preliminary experiments on issues like DR indexing based on different approaches, similarity measurement in DR network, and lastly, a brief example of using neighborhood information to suggest potential DR related concepts in retrieval query processing.

IMPROVING DESIGN RATIONALE CAPTURE DURING EMBODIMENT DESIGN

**van Schaik, Jeroen Robbert; Scanlan, Jim; Keane, Andy; Takeda, Kenji; Gorissen, Dirk**

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Design rationale can help solve difficult problems, aid design reviews and make design reuse easier. It is observed that the capture and reuse of rationale tends to decrease during the detail design phase. The inability to connect rationale to geometry is identified as a probable cause. A solution is proposed to increase the ease of design rationale capture during detail design by creating links between design rationale nodes and the corresponding parameters in the CAD design. Further implementation and testing of these concepts is discussed.

ADAPTING AEROSPACE DESIGN RATIONALE MAPPING TO CIVIL ENGINEERING: A  
PRELIMINARY STUDY

**Eng, Nathan Lee (1); Marfisi, Emanuele; Aurisicchio, Marco (1)**

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A pilot study of aerospace design rationale capture methods in civil engineering was performed to improve support for information management and systems thinking. Deploying software-based methods in complex socio-technical environments presents many challenges. Digital tools are often force-fit into work in ways that disrupt communication and understanding. This study seeks to mitigate potential disruptions through careful study of opportunities for innovative, localized variations in civil engineering. Data was collected through adaptation of existing documents into map-based formats, examination of information repositories and informal interviews with engineers exposed to the mapping methods on a live project. Results echo previous work comparing these industries: highlight current limitations of “paperless” visions and pointing to adapted mapping methods that better fit the civil engineering context. Future work will develop those methods in collaboration with more engineers over longer studies to demonstrate further impact on the everyday work and the kinds of holistic thinking required for global competitiveness and sustainable design of the built environment.

FACING THE OPEN INNOVATION DILEMMA – STRUCTURING INPUT AT THE COMPANY’S BORDER

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1: Technische Universität München, Germany; 2: IMAN Solutions GmbH

Open innovation makes the company's border permeable for knowledge exchange with outside world. Various ways exist on which ideas can flow into the company's product development process as well as flow out into the market. Each direction faces its own challenges. However bringing input to the company poses the problem to prepare the input in the expected way and to identify the proper receiver within the company. Here we show that a framework supports preclustering and evolvment of input before transferring it into the company. From a conducted case study we learnt that the contributed ideas mainly concerned the embodiment level, but also principle and function level. Our results demonstrate how the framework can be instantiated for a specific tool. The framework is not method specific and thus can be applied to various open innovation approaches aiming into the company.

STUDY ON THE INTRODUCTION OF DESIGN MANAGEMENT IN THE PRODUCT DEVELOPMENT PROCESS OF BRAZILIAN CLOTHING COMPANIES

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FEDERAL UNIVERSITY OF RIO GRANDE DO SUL, Brazil

Design is generally associated with the aesthetic and functional factor of products. However, since the 90s, this concept has changed and the meaning of this term has become more comprehensive. Presently, this word is associated to strategic factors within organizations. The goal of this research is to study the introduction of design management in the product development process of Brazilian clothing companies. The theoretical framework of this research shows that the curriculum frameworks of the design schools in Brazil do not yet sufficiently emphasize management in the courses of this area, making it impossible for designers to develop managerial abilities. Above all, the present study aims at analyzing how the clothing companies in Araranguá, in the state of Santa Catarina – Brazil, introduce design in their processes. The analysis was carried out via a comparison with the Design Management Model presented by authors Bruce; Cooper and Vazquez as a guiding element of this research. The sample encompasses five companies that are developers of fashion products, the qualitative data analysis of which resulted in suggestions for improvement to each company studied.

A FRAMEWORK FOR DEVELOPING VIABLE DESIGN METHODOLOGIES FOR INDUSTRY

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1: Tampere University of Technology, Finland; 2: Konecranes Corporation; 3: Wärtsilä Corporation

In this paper we propose the most serious shortcomings that restraint the use of academic design methodologies in industry. The focus is on the level of clarity on the design goals, formulated as: “How much do we know about the design goal in the beginning?” We use a framework to illustrate the differences of the methodologies. When we compare the design processes and include also the industrial experiences we can see that a lot of knowledge and experience is needed to be able defining clear design goals and list requirements. There is clear need to develop approach that facilitates capturing the design goals and design rationale of the particular design process. The design intent, design object, amount of preset technical sub-solutions, level of knowledge on the technical system and the surrounding culture with belief systems, norms and constraints needs to be available in order to apply the design process successfully in industrial context.

EMBODIMENT DESIGN THROUGH THE INTEGRATION OF OTSM-TRIZ SITUATION ANALYSIS WITH TOPOLOGICAL HYBRIDIZATION OF PARTIAL SOLUTIONS

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Many design approaches have been developed to support the tasks involved in the Conceptual and Embodiment design phases, but their nature has led to very different paradigms. The translation of the system concept into its structure still represents a critical task, since the models adopted for conceptual design are not directly compatible with those involved in the embodiment stage. Enhancing the interoperability of these models is therefore a key issue to improve the efficiency of the Product Cycle. According to this objective, the authors present an investigation aimed at testing the integration between OTSM-TRIZ approach to concept development and DAeMON, an original technique for multi-objective optimizations developed by the authors. The functionality of the proposed model has been tested through its application to a case study concerning the redesign of a dot printer component. The results demonstrate the potential of the integrated paradigm in guiding the designer from the identification of the right problem to solve, to the embodiment of the solution. Such experience has led to the proposition of a set of rules for developing a new framework for innovative embodiment tasks.

EMPIRICAL VERIFICATIONS OF SOME RADICAL INNOVATION DESIGN PRINCIPLES ONTO THE QUALITY OF INNOVATIVE DESIGNS

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Product-service innovation projects in industrial contexts are not yet supported by clear theories and methodologies. In the last years we have developed and experimented on a new Radical Innovation Design (RID) methodology. After introducing the RID principles and design process, we explore the relationships between the means employed during the problem setting and the problem solving stages of the conceptual design on the one hand, and the value finally produced for the company at the end of this stage on the other hand. For that purpose, we have built a protocol around innovation projects involving 86 students in 19 projects of 5 types. 61 variables have been observed, generating 700 data vectors which have been learnt by Bayesian Networks. Thanks to additional contextual variables featuring the design participants, the projects and the jury members assessing the values of the results and the means, we have derived a number of non trivial findings to successfully lead radical innovation projects in industrial contexts within the stages embracing product planning and conceptual design.

MORPHOLOGICAL ANALYSES OF A SUSTAINABLE SCHOOL DESIGN

Zeiler, Wim

Technical University Eindhoven, Netherlands, The

The built environment has to become more sustainable. Principals experiment with different ways to stimulate Integral D0esign teams, in which designers from different disciplines start designing together almost from the same moment in the design process. The design competition session for the conceptual design of a sustainable school was put on video and analyzed by applying morphological analysis. This analysis is based on a functional transcript of the process and the transforming of that in to a morphological overview. That overview represents the interpretation of the design brief by the design team as well as the solutions known within the design team related to them. This analysis is done in two ways: one focusing on the process interactions and one more focusing on the functional aspects of the design process. Some results of the analysis are presented especially focusing on the difference between architects and engineers in the design process.

IDEA SCREENING IN ENGINEERING DESIGN USING EMPLOYEE-DRIVEN WISDOM OF THE CROWDS

**Onarheim, Balder; Christensen, Bo**  
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The paper investigates the question of screening ideas in the ‘fuzzy front end’ of engineering design, examining the validity of employee voting schemes and related biases. After an employee-driven innovation project at {Company Name removed for review}, 99 ideas were to be screened for further development. Based on the concept of ‘wisdom of the crowds’, all ideas were individually rated by a broad selection of employees, and their choices of ideas and idea categories compared to those of a small team of senior marketers. The study also tested for two biases: visual complexity and endowment effect/ownership of ideas. The study shows that the crowd wisdom of employees significantly correlates with the preferences of the marketing team: overall, in top 12 selected ideas and in choice of idea categories. This match increases when including only the ratings of the most experienced employees. The experienced employees also proved to be less affected by visual complexity in the ideas presented. The endowment effect was potent in that every employee proved to be more likely to select their own ideas over others, but this effect disappeared when aggregating across the crowd of employees.

PRODUCT PROFILE TO REDUCE CONSUMER DISSATISFACTION IN TERMS OF SOFT USABILITY PROBLEM AND DEMOGRAPHICAL FACTORS: AN EXPLORATORY STUDY

**Kim, Chajoong; Christiaans, Henri**  
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As consumer electronic products have increased in complexity and users of those products are still from a broad variety of the population, new complaints related to product usability are identified. Consumer dissatisfaction is increasingly caused by soft usability problems they experience, problems that have nothing to do with technical failure. This phenomenon bothers companies of electronic products because it will probably lead to a decrease of brand loyalty. Therefore, the paper explores the relationship between soft usability problems, demographical factors and product attributes through a survey of 102 users from the Netherlands and South Korea. The results reveal that product profiles in terms of product complexity and product intimacy are related with specific soft usability problems and some demographical factors. This finding implies that a product profile can be a useful source of understanding problems experienced with them. Moreover, it can help preventing usability problems leading to an increase of consumer satisfaction and brand loyalty.

THE IMPORTANCE OF EMPATHY IN IT PROJECTS: A CASE STUDY ON THE DEVELOPMENT OF THE GERMAN ELECTRONIC IDENTITY CARD

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Although there is a great interest in user driven innovation, IT industry still shows a strong focus on technology driven innovation development. Understanding the perspective and social context of the user is also not part of a regular technical education. As a result, IT development has the tendency to concentrate on technical issues while missing the users’ actual needs. In our case study on the implementation of the electronic identity card (e-IC) in Germany, we explain how this overlook of the user causes serious project failures and product errors. We argue that the lack of user-centeredness is a direct result of the underestimated value of empathy and empathic knowledge within IT projects. Beyond that we regard empathy as the most important capability, which is being developed by design thinking. Design thinking is a user-centered and problem-solving approach. In this work we hypothesize, that the more active attention is paid to empathy throughout the project, the less likely are unfeasible products, increasing costs and avoidable time delays.

THE SCENARIO OF USER EXPERIENCE

**Ortiz Nicolas, Juan Carlos; Aurisicchio, Marco**  
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A steady stream of research in user experience (UX) has been produced in recent years, however, the published works in the form of theories, models and frameworks have not been reviewed and analysed to synthesise the gained knowledge. To address this issue, this article presents one such review of many of the existing frameworks and models that can be found in the different disciplines that comprise the fields of experience and design. The most relevant actors of these models have been extracted and synthesized into a scenario in which user experience develops. Four actors have been identified that have a strong impact on user experience: the user, interaction, artefact and context. Each actor is reviewed in detail, along with an explanation of its most relevant aspects.

EXPLORING CONSUMER NEEDS WITH LEWIN'S LIFE SPACE PERSPECTIVE

**Kim, Kee-Ok; Hwang, Hye-sun**  
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Consumer needs are assumed to be originated from tensions between perceptions of the self and the environment by which the whole psychological field, life space, is developed. Dual research problems are developed from this proposition; one is to approach a basic framework of consumer life space and the other is to explore consumer needs from different life spaces for comparing distinctive characteristics within and across different life spaces. The former is developed with three nations’ time use studies from which all possible human activities are listed, clustered, and re-clustered to obtain a basic framework for consumer life spaces. Three GT studies collect consumer needs on learning, a kitchen, and an imaging device for representing those needs from a self, a family, and a leisure/cultural life space, respectively. Consumer needs are repeatedly clustered and underlying three dimensions in consumer needs are deduced: self- vs. others-oriented, functional vs. emotional, and autotelic vs. instrumental. The three dimensions produce eight types of consumer needs, with which distinctive characteristics of consumer needs from different life spaces become manifested.

AN APPROACH TO ANALYSING USER IMPRESSIONS AND MEANINGS OF PRODUCT MATERIALS IN DESIGN

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To approach the essence of design for emotion and experience, this paper focuses on tactile interactions with product materials. We propose a framework for analysing tactile interactions based on human association-based in-depth impressions and interpretation-based created meanings. The aim of the study is to answer how in-depth impressions activate created meanings in tactile interaction and how do they affect human preference with regards to product materials. To detect and identify in-depth impressions and created meanings, this study applies original methods that analyse concept networks. To collect human freely expressed impressions and preferences we conducted an experiment that involved seven material samples. The identified in-depth impressions and created meanings are connected with preference evaluations during a tactile interaction with product materials. According to the findings, the generation of fewer but strong in-depth impressions activate diverse and original created meanings with respect to a material; and positively affects preference evaluation. These findings should contribute to design that leads to users’ emotional bonds and meaningful experiences.



SOFTWARE SUPPORTED KNOWLEDGE TRANSFER FOR PRODUCT DEVELOPMENT

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The pinngate project aims to display product development knowledge appropriately und user-specific. To achieve this objective the following considers the knowledge transfer process starting at a teacher or an expert to a learner or student. From the comparison of the detailed consideration of the knowledge transfer process to the extent available on the market-standard software follow usage scenarios and research fields.

CAPTURING THE CONCEPTUAL DESIGN PROCESS WITH CONCEPT-CONFIGURATION-EVALUATION TRIPLETS

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Design knowledge is a key asset that companies find difficult to capture and access. Since most design is redesign, being able to use prior knowledge effectively is crucial. A record of the design process and the decisions that were made is necessary in order to understand, recreate and modify a design. Not less important is capturing the rationale behind rejected ideas. Various design methods can be used for the conceptual design phase, but most fail to explicitly capture the history and rationale of the process, including the reasons for discarded efforts. This paper demonstrates the need for capturing the design rationale with a textbook example that uses functional decomposition and morphology as the conceptual design method. It then introduces a simple and effective scheme that uses a sequence of triplets of the form concept-configuration-evaluation to describe the desired information. This scheme is based on a conceptual design methodology called parameter analysis, but we show that the proposed means of rationale capture is generally applicable.

A NEW METAMODEL TO REPRESENT TOPOLOGIC KNOWLEDGE IN ARTIFACTUAL DESIGN

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This paper presents the Topology Abstraction Representation Diagram (TARD) as a new metamodel to represent knowledge about components and their relations for the purpose of Computational Design Synthesis (CDS) of artifactual routine design. TARD consists of three building blocks: elements, c-relations and h-relations. Elements represent components of an artifact by grouping parameters. C-relations represent the connectedness of the elements in the topology. H-relations model how a group of c-relations describes the composition of one level of abstraction and its relation with other levels of abstraction. One important characteristics of TARD is that topology knowledge is modeled in both a declarative fashion as well as in a procedural fashion. This enables the representation of existing artifacts as well as it models knowledge about how to configure new design artifacts. TARD decouples levels of abstractions by using explicit hierarchical relations (h-relations) and decouples the connectedness among elements by using explicit connection relations (c-relations). By doing so, each level of abstraction can be generated one independent from another.

A SCALABLE APPROACH FOR THE INTEGRATION OF LARGE KNOWLEDGE REPOSITORIES IN THE BIOLOGICALLY-INSPIRED DESIGN PROCESS

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Many applications of Biologically-Inspired Design (BID) are well-known and research is increasingly focusing on methodologies towards systematic BID. However, currently no ideation tool exists that is able to leverage the large textual biological resources in a scalable way to propose a selection of biological strategies that are interesting for a specific design problem under focus. This paper first identifies the main bottleneck preventing the realization of such a scalable BID ideation tool by analyzing the state-of-the-art in systematic BID. It is observed that most work focuses on developing detailed models of, both biological and engineering systems, which enable support during knowledge transfer between the two domains. However, the automated instantiation of these models for a large collection of biological strategies currently remains an open question and domain experts are necessary to complete this time-consuming and expensive task. Therefore, a new approach is proposed that uses a conceptual representation of the biological domain to identify candidate biological strategies as input for the transfer phase.

PROVIDING DESIGN SOLUTION REPOSITORIES IN THE FIELD OF MECHANISM THEORY

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Solutions for most present-day problems in the field of motion systems can be derived from existing designs. Unfortunately, large portions of this knowledge are difficult to access, since it is scattered over the world's libraries, museums, companies, universities, and other institutions. Also, it is stored in various forms, like textual descriptions, images, or diagrams.

In recent years there have been efforts to digitalize sources of design solutions and make them available on the Internet. However, most of these repositories represent information in a way that does not meet the requirements of engineering designers concerning the retrieval of specific solutions. The presented paper discusses methods and tools necessary to extract solutions from sources and to describe them with metadata based on terms and concepts of motion science.

MEANS FOR INTERNAL KNOWLEDGE REUSE IN PRE-DEVELOPMENT – THE TECHNOLOGY PLATFORM APPROACH

Corin Stig, Daniel; Bergsjö, Dag

Chalmers University of Technology, Sweden

This paper deals with challenges regarding the design and implementation of a technology platform framework. The framework is intended to be used as a basis for pre-developent also called technology development and when designing and configuring new products. Since technology platforms enable more reuse on a higher abstraction level compared to traditional product platforms, several challenges arise. This paper will elaborate on organizational needs and tools for facilitating the internal knowledge reuse. In this context web based tools and checklists will be introduced. There is also a discussion regarding wiki tools and implementation of IT support tools. The research has been done in close collaboration between Chalmers University and a Swedish supplier in the aero engine industry.

A PARAMETRIC DESIGN FRAMEWORK TO SUPPORT STRUCTURAL AND FUNCTIONAL MODELING OF COMPLEX CONSUMER ELECTRONICS PRODUCTS

Seki, Kenichi (1); Nishimura, Hidekazu (1); Zhu, Shaopeng (1); Balmelli, Laurent (2)

1: Keio University, Japan; 2: IBM Software Group

Today's market demand for smaller and more powerful consumer electronic devices poses a major challenge to the rapid design of products. In addition, the ability to perform strategic coordination among different stakeholders within the enterprise increasingly becomes an important criterion for global engineering. In this study, we first introduce a typical design process involving distributed design teams. In particular, this process allows a thermal–acoustic design of cavities, i.e., air space inside the enclosure, in terms of flow rate and acoustic radiation resistance. Then, we investigate a module-based design optimization approach defining cavity as a module to efficiently support such processes. We ensure the design control of both cavity characteristics in an internationally distributed project through design data analysis using the Systems Modeling Language (SysML) and the resulting product model descriptions of the system architecture.

# Design Research Methodology

Theme: Design Theory and Research Methodology  
Chair: Hatchuel, Armand

## DESCRIPTION, PRESCRIPTION AND “BAD” DESIGN

Winkelman, Paul

University of British Columbia, Canada

Design methodologies can serve the purposes of description, prescription, or the creation of norms. A given methodology can display features of all three. In such cases, does the presence of all three compromise the validity of the methodology? The mixing of the descriptive with the prescriptive is common in both science and engineering. Science often requires a theory (prescription) to enable us to make sense of what we are seeing (description). Within engineering, mathematics draws the descriptive and the prescriptive together; at first glance, mathematics appears merely descriptive, but the unwavering trust placed in its constructs give it prescriptive powers. Thus, one would expect models of the engineering design process to be ambiguous without diminishing the methodology. The normative presents its unique challenges for engineering research, for the normative suggests that we need to espouse certain values and this detracts from the logic of design.

## A NOTE ON THE DEBATE ON SCIENTIFIC PROCESS VS. DESIGN PROCESS

Motte, Damien; Björnemo, Robert

Lund University, Sweden

It has often been mentioned that the scientific process is quite opposite to the design process, mainly consisting in the analysis of existing phenomena in order to develop a theory, the design process being a synthesis act that creates something new into the world. In the light of the developments that led to this conception and with reference to the current view on the scientific process, it is argued that the scientific process has more similarities with the design process than differences. As parallels can be drawn between both processes, some implications for further research onto the fundamentals of the design activity are discussed.

## DEVELOPMENT OF AN EVALUATION FRAMEWORK FOR IMPLEMENTATION OF PARAMETRIC ASSOCIATIVE METHODS IN AN INDUSTRIAL CONTEXT

Salehi, Vahid; McMahon, Christopher A

University of Bath

This paper presents a study of the evaluation phase of a project that developed a new method to support parametric and associative computer-aided design, PARAMASS, in an automotive design context as an example of the systematic evaluation of new methods in design research. The evaluation employed qualitative and quantitative techniques to obtain the reaction of practising designers to the new method and to identify the time benefits of the application of the method in the design of automotive engines. The paper first presents a general overview of quantitative and qualitative methods, and describes systematic evaluation approaches in other domains especially software application. It then presents the evaluation of the PARAMASS approach using qualitative evaluation based on the Goal-Question-Metric approach, questionnaires and interviews of designers, and the qualitative evaluation based on the Use Case approach. Considerations in the planning and implementation of the evaluation procedures are presented.

## DIMENSIONS OF OBJECTIVES IN INTERDISCIPLINARY PRODUCT DEVELOPMENT PROJECTS

Albers, Albert; Lohmeyer, Quentin; Ebel, Bjoern

Karlsruher Institute of Technology (KIT), Germany

Interdisciplinary product development is a complex and uncertainty-affected system and objectives are central elements of it. In consequence the handling of these objectives, characterized by a high connectivity and dynamic, demands for a multi-dimensional view on objectives. This paper examines the nature of objectives and generates a conceptualization of four generalized dimensions of objectives: degree of maturity, degree of rigidity, leverage and impact. Based on these dimensions the approach of objective dimension matrices (ODM) is deduced. ODM considers product development as a socio technical system and therefore enables a systematic handling of objectives in order to understand their role in interdisciplinary product development projects. The capability of ODM is demonstrated by its application within the development of a new humanoid robot.

# Managing Product Failure and Uncertainties

Theme: Design Methods and Tools  
Chair: Gooch, Shayne

## FAILURE MODE AND EFFECTS ANALYSIS IN COMBINATION WITH THE PROBLEM SOLVING A3

Lodgaard, Eirin (1); Pellegård, Øystein (2); Ringen, Geir (2); Klokkehaug, Jon Andreas (3)

1: SINTEF Raufoss Manufacturing AS, Norwegian University of Science and Technology, Norway; 2: SINTEF Raufoss Manufacturing AS; 3: Norwegian University of Science and Technology, Norway

Failure Modes and Effects Analysis (FMEA) is a methodology that may contribute to identify and reduce risks during the product design phase. Although this is a widely used methodology within several fields; it has nevertheless many limitations and challenges. Traditional FMEA process was applied during the design phase of the company involved in this study. The FMEA methodology is discussed and evaluated and an evolved method to improve problem solving and root cause detection is proposed. The results show that the formal fulfillment of the method is not sufficient by itself to achieve efficiently quality and reliability improvement on the product design. Consequently, to succeed with the FMEA methodology it is proposed to combine it with the A3 problem solving methodology for a deeper analysis of the root causes for the prioritized issues during the risk reduction process.

## IFMEA – INTEGRATION FAILURE MODE AND EFFECTS ANALYSIS

Punz, Stefan; Follmer, Martin; Hehenberger, Peter; Zeman, Klaus

Johannes Kepler University, Austria

During the product development process a lot of challenges have to be mastered. Beside ever shorter innovation cycles and time-to-market, products with increasing complexity such as mechatronic products lead to greater development risks. Mechatronic products are characterized by high functional as well as physical (e.g. spatial) integration. This integration of several modules (sub-systems) from different engineering disciplines entails a high risk of product failures. It is therefore crucial to systematically identify these risks already in early design stages. Therefore, it is important to realize that systems (sub-systems, system-elements, modules) are carriers of different physical effects. These effects not only realize the function of the system, but may sometimes have also undesired side effects which may lead to problems for other modules and, hence, have to be considered carefully. In this paper, the IFMEA (Integration Failure Mode and Effects Analysis) method is introduced, which is based on the widespread FMEA (Failure Mode and Effects Analysis) method, but has its focus on identifying problems due to the integration of several modules within mechatronic systems.

## LINKAGE OF METHODS WITHIN THE UMEA METHODOLOGY - AN APPROACH TO ANALYSE UNCERTAINTIES IN THE PRODUCT DEVELOPMENT PROCESS

Engelhardt, Roland Alexander; Eifler, Tobias; Mathias, Johannes; Kloberdanz, Hermann; Birkhofer, Herbert; Bohn, Andrea

Technische Universität Darmstadt, Germany

In its entire life cycle every product is exposed to different uncertainties. In technical systems, these uncertainties are generally understood as deviations from product and process properties. In the development processes uncertainties particularly occur when modelling and forecasting technical or economic product and process properties. The Uncertainty Mode and Effect Analysis (UMEA) Methodology forms a strategic procedure to analyse uncertainties and their consequences.

The Objective of this paper is to show the use of methods within the UMEA Methodology during the phases of the product development process. In doing so uncertainties are recorded and described systematically at all virtual and real life cycle processes. In order to implement the UMEA, methods were allocated to different phases of the product development process. As shown in the following, particularly in their combination and interlinking these methods allow the detection and evaluation of uncertainties.

## UMEA - A FOLLOW UP TO ANALYSE UNCERTAINTIES IN TECHNICAL SYSTEMS

Engelhardt, Roland; Wiebel, Marion; Eifler, Tobias; Kloberdanz, Hermann; Birkhofer, Herbert; Bohn, Andrea

Technische Universität Darmstadt, Germany

In mechanical engineering uncertainties occur during the entire life cycle of a product. These uncertainties are defined as deviations from process and product properties. This makes the development of a comprehensive methodology for analysing uncertainties necessary. The methodology is called Uncertainty Mode and Effects Analysis (UMEA) and consists of a strategic procedure to analyse uncertainties and their consequences. These uncertainties appear for example by different process operations or by variations during the utilization process of the product. In planning and development processes uncertainties must be taken into account particularly in the modelling and forecasting of the technical, environmental and economic product and process properties. The integrated UMEA methodology is based on a comprehensive model of uncertainty, which allows the consideration of uncertainties in all life cycle phases to describe and to evaluate the impact of uncertainties systematically.

# Methods and Tools for Sustainable Design I

Theme: Design for X, Design to X  
Chair: Caillaud, Emmanuel

## DESIGNING SUSTAINABLE SOCIETY SCENARIOS USING FORECASTING

**Mizuno, Yuji; Kishita, Yusuke; Wada, Haruna; Hiroasaki, Maki; Fukushima, Shinichi; Umeda, Yasushi**

*Graduate School of Engineering, Osaka University, Japan*

Environmental problems such as resource depletion or climate change are the most serious problems for society and industry. In order to deal with such problems, scenario writing is a useful methodology for envisioning ideal future, such as sustainable society. Although describing these scenarios requires a lot of time and a large amount of works, there is no computational support for it. In order to resolve this problem, this paper proposes a design methodology of scenarios based on forecasting approach, which explores future from current situation. In order to realize computational scenario design support, we formalize the design process as four steps; setting problems, constructing causal networks, describing storylines, and describing scenario texts. And we develop Scenario Design Support System for supporting the scenario design process on a computer. For testing the proposed methodology, we designed “Electric Vehicle Diffused Society Scenario” as a case study. In the case study, proposed process and design support methodology are useful for designing a forecasting scenario.

## WHICH GUIDELINE IS MOST RELEVANT? INTRODUCTION OF A PRAGMATIC DESIGN FOR ENERGY EFFICIENCY TOOL

**Rath, Karola; Birkhofer, Herbert; Bohn, Andrea**

*TU Darmstadt, Fachgebiet für Maschinenelemente und Produktentwicklung, Germany*

Energy efficiency is a topic of high importance in companies nowadays. As a knowledge deficit exists concerning the design of energy efficient products there is a significant need for comprehensive tools and methods supporting the designer to integrate energy aspects into the design process. Existing methods, particularly guideline-based tools are only little user-friendly as they do not support a systematic and selective access to guidelines that are most relevant to solve a specific problems.

This paper introduces a new guideline-based tool that provides a hierarchical structure and clustered guidelines and therefore eases targeted access to guidelines most relevant in a certain development context. This tool is intended to allow product designers to reduce the energy consumption of products during material processing, manufacturing, use, recycling and disposal. It is moreover integrated into a design approach for energy efficient products and accordingly serves as a pragmatic tool.

## SUSTAINABILITY INNOVATION IN EARLY PHASES

**Panarotto, Massimo; Törlind, Peter**

*Luleå University of Technology, Sweden*

Sustainability is a complex but extremely important issue. To achieve a new industrial revolution that focuses on sustainability, we need innovation. Just improving our technologies and our habits will not save our planet from its current gradual degradation.

In recent decades many Eco-tools have been developed; this paper evaluates the most important and used today, how they help to consider sustainability in the product development process and identify important and missing characteristics, arguing that many eco-tools were experienced by the companies as too complex and time-consuming and often not aid the innovation process. These characteristics guided the development of a new framework for sustainability innovation based on a multidisciplinary workshop approach. It focuses on analyzing customers from a sustainable viewpoint, understanding their real needs, using ideation tools to generate ideas in areas not usually considered in current eco-tools, e.g. changing customer behavior or the business model. The method was developed, tested and evaluated in an iterative approach over a six-month period.

## SUCCESS CRITERIA FOR IMPLEMENTING SUSTAINABILITY INFORMATION IN PRODUCT DEVELOPMENT

**Aschehoug, Silje Helene; Boks, Casper**

*Norwegian University of Science and Technology, NTNU, Norway*

The novel contribution of this article is the result from a group creativity session with product designers in the automotive industry supply chain with the purpose of developing success criteria for the implementation of sustainability information use guidelines. The guidelines highlight relevant information from each stakeholder, and may be used to support and strengthen sustainable product development in firms in addition to using traditional product and process data. A number of 79 unique ideas were identified by the participants, 60 of these being both feasible and relevant for implementation purposes. These 60 ideas were then grouped into nine separate categories. The ideas generated from the participants range from traditional implementation issues such as management commitment, customer or regulatory demands and sufficient competence within sustainability issues, to more novel ideas including the development of a task force for sustainable development within the industrial cluster that the case firms are part of. Moreover, increased collaboration with academia was highlighted as important for the successful implementation of sustainability information use guidelines.

# Shaping the Engineering Designer

Theme: Design Education  
Chair: Hansen, Claus Thorp



## FOUNDATIONS FOR A NEW TYPE OF DESIGN-ENGINEERS – EXPERIENCES FROM DTU

**Jorgensen, Ulrik; Lindegaard, Hanne; Brodersen, Søs; Boelskifte, Per**

*Technical University of Denmark, Denmark*

Since 2002 a new design-engineering education has been organized at the Technical University of Denmark. It fulfils most of the requirements in the CDIO concept but builds in addition on a change in what is considered core disciplines in engineering as three fields of knowledge are represented almost equally in the curriculum: natural and technical sciences, design synthesis and socio-technical analysis. Combined with an integration and co-ordination of disciplines, a series of projects providing a progression of challenges to the students’ learning, and a focus on the outcomes of the learning processes of competences needed in design engineering, the curriculum represents a radical innovation in engineering curriculum.

The paper describes the background as well as the foundational elements constituting the educational program and presents an assessment of the key factors that has made it attract new groups of students to engineering. An evaluation has been carried out based on their own and their employers experiences. This supports the visions build into the curriculum and adds important components to what might be needed to carry out reforms in engineering education.

## TEACHING DESIGN FOR ENVIRONMENT IN PRODUCT DESIGN CLASSES

**Baeriswyl, Michael C. (1); Eppinger, Steven D. (2)**

*1: ETH Zürich, Switzerland; 2: Massachusetts Institut of Technology, Boston, USA*

The paper presents an approach to teaching design for environment (DFE) in the context of a product design and development course. The teaching method has been applied in our classes for graduate engineering, business, and design students. Our approach includes a step-by-step DFE process and utilizes a recent Herman Miller chair as a case study to illustrate the successful application of each step in the process. The DFE process steps are based on our research at Herman Miller and on several published studies that investigated the integration of DFE into the product development process and which we assembled into the step-by-step DFE process. Furthermore, the teaching method includes a new approach to life cycle thinking by relating the product life cycle to the natural life cycle in order to from a closed-loop system.

## SHAPING THE INDIVIDUAL DESIGNER: PARTICIPATORY DESIGN IN EMERGENCY CONTEXT

**Briede Westermeyer, Juan Carlos; Cartes, Jorge; Bustamante, Alejandro; Perez, Marcela**

*Universidad del Bio-Bio, Chile*

This article deals about the user centered teaching-learning and design methodology used by teachers and students in the industrial design setting. The purpose of such approach is to create and strengthen attitude competences regarding knowledge and know-how. The context is the earthquake and tsunami hitting Chile on February 27th, 2010, where the “user centered design methodology is applied in object based setting up for the emergency housing context”. This approach involves the final user from the beginning of the working proposal. Such learning method allowed students to identify users’ basic needs, along with other requirements that are part of the dwelling features and also related to upper needs, which, to be tackled, assume that individuals should be observed from ‘psychical’ – ‘emotional’ – ‘cultural’ viewpoints, by the time feasible solutions are considered. This methodology is analyzed from an Industrial Design professional education viewpoint, thus illustrating all factors to be taken into consideration for the design of solutions that meet people’s needs to make their dwelling worthy in case of emergencies.

## CHARACTERIZATION OF LEADERSHIP WITHIN UNDERGRADUATE ENGINEERING DESIGN TEAMS THROUGH CASE STUDY ANALYSIS

**Palmer, Gary; Summers, Joshua**

*Clemson University, United States of America*

The paper explores leadership that exists within undergraduate engineering design teams. Often, leadership is described based on managerial styles, leadership types and styles, emotional intelligence, and work climate. However, little work explores leadership specifically within engineering and educational environment. The motivation of this research is further inspired based on the researcher’s own experience in undergraduate engineering design teams and the lack of formal leadership structure and training in typical engineering education programs. Leadership is identified in this research through conducting case study research by examining two undergraduate engineering design teams addressing different projects in different course settings. The results and conclusions from each study are extracted by triangulating within and across each of the data collection methods. Through these two case studies, leadership is clearly found present in both cases and with task-oriented leadership being the more prevalent type.



Innovation and Entrepreneurship in the Automotive Business



**Hasse Johansson**  
*Chairman of the Board  
Vinnova (Swedish Agency for Innovation Systems)*

Abstract

The global automotive business is one of the most competitive environment you can imagine. As an independent inventor or as a small development company it is very challenging to be successful in implementing new ideas and components. In this mature and somewhat conservative technical environment you really need to have a strong and revolutionary proposal. The big global manufacturers of vehicles have tried almost everything when it comes to new technology. When approaching them you need to have your idea well protected by patents and also reliable data to prove and convince that your invention have appropriate benefits.

The timing of the dialog with a potential user or business partner is important when it comes to which issues that have highest priorities or are most frequently discussed in the organization of said user or business partner. If there exist a special issue that your idea address you will have a much better access the decision making process and get enough interest for a potential business deal.

After 20 years as a supplier of engineering services to the automotive industry and 10 years as head of Global R&D at Scania CV AB, I have experienced pros and cons both from a supplier perspective as well as from a vehicle manufacturer perspective.

Biography

- Master of Science (Electrical Engineering)
- Former Executive Vice President & Head of Research and Development at SCANIA
- Chairman of the Board in Vinnova, the Swedish Governmental Agency for Innovation Systems

Graduating from Chalmers University of Technology with a Master of Science and Electrical Engineering, Hasse Johansson joined Svenska Philips AB as a Service Engineer in 1974. A year later he became Engineering Manager at SEM AB. In 1982 Hasse Johansson founded Mecel AB (which became a part of Delphi Delco Electronics Systems 1990) in which he held the position as Managing Director until joining Scania in 2001. He was also Director of Advanced Engineering Europe from the year 1995, Business Director of Mobile Multimedia Europe from the year 1999 and Engineering Director of Delphi Delco Electronics Systems Europe from the year 2000. At Scania he was appointed Executive Vice President and Head of Research and Development in 2001.

In 2010 Hasse Johansson retired from his position at Scania and is now Chaiman of the Board in Vinnova, the Swedish Governmental Agency for Innovation Systems, Lindholmen Science Park AB, Alelion Batteries AB and Dynamate Industrial Services AB. He is also Member of the Board in Electrolux AB, Fouriertransform AB, Calix Group AB and Skyllbergs Bruk AB.

Arduino & RepRap: Creating Wealth by Giving it Away

Abstract

Because it is sometimes possible to convert one into the other, money and wealth are often confused. But they are distinct: money is pieces of paper or numbers in a computer; wealth is corn to make bread, or a motor car. Both money and wealth grow as time advances: growth in money is inflation, growth in wealth is longevity and prosperity. Is it possible to grow wealth independently of money?

This talk will be from Adrian Bowyer - creator of RepRap, the open-source replicating 3D printer - and from David Cuartielles - creator of Arduino, the open-source microcontroller. Both projects have founded significant and growing industries - and hence significant and growing wealth - by giving away all the data required to build RepRaps and Arduinos completely free. They have also short-circuited most conventional industrial infrastructure by placing the ability to create wealth directly in the hands of private individuals.

The presenters contend that this is the way of the future: companies, and - more importantly - those private individuals will be giving away their primary products and making a living on the sideline activities that such donations attract.

Software has been heading in that direction for decades. Now hardware is following.

Biography



**Adrian Bowyer**  
*BSc(Eng) PhD CEng CMath ACGI  
MBCS FIMA FRSA  
Senior Lecturer  
Founder of RepRap  
RepRap / University of Bath*

In the early 1970s Adrian Bowyer read for a first degree in mechanical engineering at Imperial College, London, and then researched a PhD in tribology there. In 1977 he moved to Bath University's Maths Department to do research in stochastic computational geometry. He then founded the Bath University Microprocessor Unit in 1981 and ran that for four years. After that he took up a lectureship in manufacturing in Bath's Engineering Faculty, where he is now a senior lecturer.

His current area of research is self-replicating machines - he is the inventor and developer of the RepRap replicating rapid prototyper.

He also works on geometric computing (he is one of the authors of the Bowyer-Watson algorithm for Voronoi diagrams), the application of computers to manufacturing, the biochemistry of smart materials, and biomimetics.



**David Cuartielles**  
*MSc PhD  
Founder and leader of the  
prototyping laboratory  
Malmö University*

David is a candidate in Interaction Design for the School of Arts and Communication at Malmö University, Sweden. He is the founder and leader of the prototyping laboratory there since 2001.

In 2005 co-created the Arduino prototyping platform and since then runs the web-unit of the project dedicated to give support to the user and developer community. In 2006 curated the Electrolobby space of the Ars Electronica Festival, which was dedicated to the DIY movement with a series of workshops in quick prototyping. In 2009 created the 1scale1 open source prototyping company specialized in the creation of HiFi prototypes of wearable computers.

Also since 2010 is part of the Medea research group collaborating with the city of Mamo in creating the first FabLab facility in the region to open in 2011.

DESIGNING PATENT PORTFOLIO FOR DISRUPTIVE INNOVATION – A NEW METHODOLOGY  
BASED ON C-K THEORY

Felk, Yacine (1,2); Le Masson, Pascal (1); Weil, Benoit (1); Cogez, Patrick (2); Hatchuel, Armand (1)

1: CGS - center for management science, Mines Paristech, France; 2: Technology R&D, STMicroelectronics, Crolles, France

In this paper we explore a key element of knowledge intensive innovation, the issue of patent generation. Whereas patent is often considered as a 'by-product' (output) of design activity, we focus on the situation of disruptive innovation, where recent studies in management of innovation have shown that patent is particularly crucial. Only few methods are based on patent modelling, they rely most of all on problem solving design reasoning. Nevertheless, these are not adapted to disruptive innovation where both creativity and problem solving are mandatory. Looking at this situation as an issue of portfolio design provides a useful heuristic for management insights of a "design for patentability" approach. Our contribution is defined in two parts, first a patent model and second, a process of patent generation. We propose to model patent information as an (Action, Knowledge, Effect) triplet. In disruptive situations, all three elements (A, K, E) are unknown. Based on this modelling, we show through an illustrative case how a team in charge of disruptive innovation exploration proposed several (A, K, E) triplets. This work suggests a method "C-K Invent" derived from C-K design theory.

CK, AN ENGINEERING DESIGN THEORY? CONTRIBUTIONS, LIMITS AND PROPOSALS

Coatanea, Eric (1); Choulier, Denis (2); Forest, Joelle (3)

1: Aalto University, Finland; 2: UTBM, France; 3: INSA Lyon, France

The CK theory developed by Hatchuel, Weil and Le Masson has raised interest and controversies in the academic and practitioners' communities. This paper is participating to this debate. After presenting the scope, focus, and the contributions claimed by its creators; the authors analyse the interest of considering also other concepts and models usually integrated in traditional design knowledge and practices. Indeed, it can be noticed that important concepts such as the concepts of function and structure for example seems to remain outside the perimeter of CK even if some of them are integrated in the research programs of the authors. This is not a central limitation if the real scope of the theory will be minimized, compared with the initial ambition of the CK's creators. It is nevertheless a fruitful contribution which explicitly creates a distinction between knowledge, concepts and notes the importance of expanding partition. The present contribution proposes to enrich the initial scope of CK by integrating theoretical contributions made by other authors and by considering concepts widely used and accepted in engineering design.

A METHOD FOR DESIGN REASONING USING LOGIC: FROM SEMANTIC TABLEAUX TO DESIGN  
TABLEAUX

Hendriks, Lex (2); Kazakci, Akin Osman (1)

1: CGS, Mines Paristech, France; 2: ILLC, Universtiy of Amsterdam

Inspired by C-K theory, the current work presents a framework demonstrating how C-K type design reasoning can be applied within logic. Building on our previous work, we extend and generalize the well-known method of Semantic Tableaux, invented by Beth for logical theorem-proving, to Design Tableaux – a general, formal procedure allowing to implement expansive reasoning within the formalism of logic. Our contribution is twofold. First, we give a formal, verifiable procedure that explicit and apply the ill-defined operators of C-K theory. Second, we contribute to the notion that design science can be useful to other fields and theories (in this case, logic) by proposing a mode of creative reasoning within a logical framework stemming directly from a theory of design

MEASURING HISTORY: DOES HISTORICAL CAR PERFORMANCE FOLLOW THE TRIZ  
PERFORMANCE S CURVE?

Dowlen, Chris

London South Bank University, United Kingdom

After an outline of the four curves proposed for measuring historical product behavior by the TRIZ system and a brief summary of previous work to determine the development of car history, the paper investigates the assessment and measurement of performance throughout the history of the car. This is done by taking a historical investigation of performance criteria such as engine power, maximum speed and acceleration. A factor analysis is also carried out on performance parameters and the first two factors are presented as a two-dimensional performance map that could be used as a design tool. The paper then questions whether this is what is really meant by car performance and discusses the difficulties of measuring this. Car developments in the late 1930s are taken as an example to illustrate some of the nuances that need to be captured. The work has indicated that the TRIZ process is a somewhat simplistic curve that doesn't take into account the historical data in this case.

INVESTIGATING ELEMENTARY DESIGN METHODS – USING AND EXTENDING THE GENOME-  
APPROACH

Zier, Sebastian; Kloberdanz, Hermann; Birkhofer, Herbert; Bohn, Andrea

TU Darmstadt, Germany

Nowadays most of the design methods introduced in literature are not new but rather modifications or further developments of existing methods. Therefore the system of methods and method descriptions has an evolutionary grown character. Hence the aim of investigating elementary methods is to develop a systematic approach for the deduction, description and improvement of design methods.

This paper shows a systematic approach for investigating elementary design methods.

Thus, in this paper the so called Genome Approach is used to model and analyze a certain number of methods from different areas. The application of this approach is revealed in examples. Both, strengths and limitations of this approach become visible.

To benefit from the strengths of this approach, first some extensions are discussed, to deal with the limitations, for the moment. Furthermore, long term possibilities to improve this approach are described.

THEORETICAL FRAMEWORK FOR COMPREHENSIVE ABSTRACT PROTOTYPING  
METHODOLOGY

Horvath, Imre

Delft University of Technology, Netherlands, The

Though abstract prototyping offers quality improvement and costs reduction in all branches of product development, it has gained popularity only in the software sector of the creative industry. This paper proposes a theoretical platform and an activity workflow for abstract prototyping of artifact-service combinations. First, the concept of abstract prototypes and the evolution of abstract prototyping are discussed. Then, an underpinning theory and a content-independent workflow are presented. It is proposed that the information constructs instantiated in abstract prototypes should demonstrate the real life operation and interaction/use processes, including the description of the conceptualized artifact-service combination, the human actors, and the surrounding environment. The stakeholders' needs should be taken into consideration not only in conceptualization of artifact-service combinations, but also at constructing the contents and demonstration of the abstract prototype. Narration and enactment are identified as two intertwined parts of demonstration. The follow up research focuses on testing the proposed methodology and its validation through complex industrial cases.

IMPROVING THE MANAGEMENT OF DESIGN PROJECT RISKS USING THE CONCEPT OF VULNERABILITY : A SYSTEMS APPROACH

Vidal, Ludovic-Alexandre; Marle, Franck; Bocquet, Jean-Claude

Ecole Centrale Paris, France

Since design projects evolve within complex environments, they must face more and more numerous, varied and interrelated risks. Therefore, traditional paradigms of project risk management must be completed by the use of new systems thinking-oriented approaches. This paper thus proposes a description of the project vulnerability management process and compares it with the traditional project risk management process in order to highlight the potential benefits of such a new systems-oriented approach. It also proposes a methodology to analyze project vulnerabilities by decomposing them into three levels: values, processes and project elements. A stressor/receptor analogy-based model is the basis to identify and evaluate project vulnerabilities. A simple index then aggregates the concepts of resistance, resilience and contribution to value creation. This enables to rank project vulnerabilities in order to assist decision-making. Finally, a case study is presented: it explains the benefits of the vulnerability approach in the case of a project in the context of the pharmaceutical industry, the aim of which was to design a decision support system and its corresponding work organization.

A COMPARISON OF THE INTEGRATION OF RISK MANAGEMENT PRINCIPLES IN PRODUCT DEVELOPMENT APPROACHES

Bassler, Denis (1); Oehmen, Josef (2); Seering, Warren (2); Bendaya, Mohamed (3)

1: Technical University of Munich, Germany; 2: Massachusetts Institute of Technology, USA; 3: King Fahd University of Petroleum and Minerals, Saudi Arabia

The management and reduction of risk is a central part of product development processes. This paper analyses the extent to which four common product development approaches address risks (waterfall model, stage gate model, design for six sigma, and lean product development). They are analyzed along the four principles of risk-driven design: 1. Identifying and quantifying risks; 2. Making risk-based decisions; 3. Reducing risks; and 4. Creating resilient PD systems. The analysis shows that the existing PD processes only partially address the four principles of risk-driven design and that they have their specific strengths and weaknesses. The paper concludes with a discussion of preliminary empirical findings through interviews and case studies on how to better integrate risk management principles into product development.

ADDRESSING THE RISKS OF GLOBAL PRODUCT DEVELOPMENT

Hansen, Zaza Nadja Lee; Ahmed-Kristensen, Saeema

The Technical University of Denmark, Denmark

Offshoring various stages in the product development process – from engineering tasks like R&D and design to manufacturing activities - can impact the development process, the product and the organisation. Some of these impacts are positive while some are negative. The negative impacts are related to rework, misunderstandings, miscommunication and lower quality. This paper investigates how the organisation can reduce the negative aspects of offshoring by presenting two possible approaches; one which lessens the exposure to situations in which these negative impacts happen and another which addresses them in the decision phase so the organisation can develop appropriate strategies for these instances.

A FREQUENCY ANALYSIS APPROACH TO ENSURE THE ROBUSTNESS OF INTERACTIONS-BASED CLUSTERING OF PROJECT RISKS

Marle, Franck; Vidal, Ludovic-Alexandre

Ecole Centrale Paris, France

Projects are dealing with bigger stakes and facing an ever-growing complexity. Project risks have then increased in number and criticality. Lists of identified project risks thus need to be decomposed, for smaller clusters are more manageable. Project interdependent risks are indeed often managed as if they were independent. An interactions-based clustering method which permitted to group risks, so that the interaction rate is maximal inside clusters and minimal outside, was presented with its associated tools and algorithms at ICED’09 conference with a case study in the entertainment industry. This article goes further into these approaches in order to obtain more robust results in order to facilitate the coordination of complex projects by reducing interfaces when dealing with risks. After some pages which introduce the problem and these approaches, we present an approach based on a frequency analysis, based on the variation of parameters of the quadratic integer clustering problem. A case study in the construction industry is finally presented (tramway design and construction project in a city). It permits to conclude on practical recommendations, conclusions and perspectives.

RECOMMENDATIONS FOR RISK IDENTIFICATION METHOD SELECTION ACCORDING TO PRODUCT DESIGN AND PROJECT MANAGEMENT MATURITY, PRODUCT INNOVATION DEGREE AND PROJECT TEAM

Grubisic, Viviane & Vasconcellos Ferreira (1); Ogliari, André (1); Gidel, Thierry (2)

1: Universidade Federal de Santa Catarina, Brasil; 2: Université de Technologie de Compiègne, France

No other type of project is in greater need of risk management than new product development projects. This is due, largely, to the innovative profile of such projects and, consequently, of the risks involved. In this context, the importance of risk management has been increasing considerably. Risk management methods rely on risk identification. Several methods for risk identification are available in the literature and each one has its own characteristics in terms of complexity, application time, and requirements for specialist and information. Therefore, it is difficult to know how to choose a risk identification method, and which criteria to employ in making the choice. Thus, in this paper, a model for the selection of a risk identification approach, considering the product design process and project management maturity, product innovation and project team, is proposed. To conclude, a discussion on what this study means to practitioners and academicians is presented.



THE MANAGEMENT OF MANUFACTURING PROCESSES USING COMPLEMENTARY INFORMATION STRUCTURES

Huet, Greg; Fortin, Clément; McSorley, Grant; Toche, Boris

Ecole Polytechnique Montreal, Canada

The reality of manufacturing planning is very different from the one of engineering design. Whereas the former must manage variables of an extrinsic nature (time, cost and quality), the latter manages the form, fit and function of the product, variables of an intrinsic nature. Information coherency between the product definition, the process plan and manufacturing resources must be maintained at all times. Complementary product structures have therefore been proposed as an alternative to the unified multi-view product models developed in earlier research. They allow users to create customized product structures which are linked together at the component level and can be managed separately. Ensuring consistency between these structures relies only on managing the links rather than attempting to maintain a unified product model. The Complementary Information Structures paradigm is fully illustrated through the example of an aircraft pylon design, where the step by step development of its manufacturing Bill of Materials is detailed.

DUAL PERSPECTIVE ON INFORMATION EXCHANGE BETWEEN DESIGN AND MANUFACTURING

Bruch, Jessica (1,2); Johansson, Glenn (1)

1: School of Engineering, Jönköping University, Sweden; 2: Mälardalen University, Sweden

This paper addresses information exchange between design and manufacturing from both perspectives. On the basis of case study research, the findings illustrate that there are differences between the information required by manufacturing and the information required by design. While the production system designer relies largely on feed-forward information concerning product-centric issues, design engineers request feedback information in form of both product-centric and project-centric information. The paper further elaborates on how information should be exchanged in order to minimise the risk of misinterpretation of transferred information.

ACQUISITION OF DESIGN-RELEVANT KNOWLEDGE WITHIN THE DEVELOPMENT OF SHEET-BULK METAL FORMING

Röhner, Sebastian; Breitsprecher, Thilo; Wartzack, Sandro

University of Erlangen-Nuremberg, Germany

The increasing requirements on technical products represent a growing challenge for the manufacturing engineering. This challenge will be met by the development of a new manufacturing technology called sheet-bulk metal forming. For the early consideration of the full potential of sheet-bulk metal forming in a design process, a design engineer has to know the process limitations as soon as possible. Hence, the objective has to be to acquire design-relevant knowledge already in the early phases of process development and to maintain this knowledge simultaneously to the further development of the process. These are the declared aims of the self-learning engineering assistance system that will carry out the acquisition and maintenance of knowledge owing to its self-learning aspect. In this article, within an evaluation of knowledge acquisition methodologies, data mining was identified as a possibility for the realization of the self-learning aptitude. The potential of data mining was shown by its application on simulation data to acquire design-relevant knowledge.

DATA MANAGEMENT PLANNING IN ENGINEERING DESIGN AND MANUFACTURING RESEARCH

Darlington, Mansur (1); Howard, Thomas James (2); Ball, Alex (1); Culley, Steve (1); McMahon, Chris (1)

1: University of Bath, United Kingdom; 2: DTU, Denmark

There is a growing interest in maximizing the value of research data through their sharing and re-use. This desire is hampered by the prevailing culture in data management during the research activity which largely ignores the potential for re-use, and by a lack of understanding of the character of research data and of the barriers to and opportunities for their re-use. The work reported here characterizes engineering design and manufacture research data and explores the context of their development and current management. Insights from the work have resulted in the authors proposing a number of new approaches and tools which provide the basis for better management practice.

KNOWLEDGE REPRESENTATION FOR SUPPLIER DISCOVERY IN DISTRIBUTED DESIGN AND MANUFACTURING

Ameri, Farhad; McArthur, Christian

Texas State University, United States of America

Online outsourcing has recently gained popularity among small and medium sized manufacturing companies as an efficient method for building flexible network of manufacturing counterparts. Several electronic marketplaces have emerged within the last few years with the objective of enabling large communities of buyers and sellers to virtually meet and establish new partnerships. Although e-marketplaces typically provide different automated search capabilities, they mainly rely on human users for final screening and evaluation of qualified suppliers. As the size of supply and demand pools increase, human-based search becomes inefficient. This paper describes an effort for enhancing the automation capabilities of web-based markets through an ontological approach. The proposed ontology is referred to as Manufacturing Service Description Language. MSDL provides formal semantic for manufacturing knowledge representation, thus enabling machine agents to actively participate in supplier discovery process.

APPLICATION OF MOKA METHODOLOGY TO CAPTURE KNOWLEDGE IN DESIGN FOR POKA-YOKE ASSEMBLY

Estrada, Gabriela (1); Lloveras, Joaquim (2)

1: CETYS University, Mexico; 2: UPC, Spain

Design For Poka Yoke Assembly-DFPYA is a new DFX created to prevent potential assembly issues since early design stages. This prevention is possible by designing the product with poka-yoke or error-proofing characteristics. DFPYA guide designers to make decisions based on poka-yoke assembly design requirements. As results of the application of these requirements designers are able to create solutions to prevent assembly issues for the specific product in development. This paper proposes the application of MOKA methodology to capture, organize and storage the poka-yoke designs that are created in a specific Company in order to reuse this knowledge in future new product development projects.

# Decision Making Processes

Theme: Design Processes  
Chair: Taura, Toshiharu

## COPING WITH DEVIATION AND DECISION-MAKING

**Eriksson, Joakim; Brannemo, Anette**

*Mälardalen University, Eskilstuna, Sweden*

Structured models, such as gated models, are used in order to manage complexity in multi-project environments. The aim in following these prescriptive models creates strong interrelationships of activities in the projects. The project system becomes sensitive to unexpected events that can influence the system negatively. When managing a project in a highly-interrelated project environment, it is not possible to anticipate every possible external influence on the project. Deviations from the planned operations are inevitable but teams rarely get credited for the skilled way in which they manage to cope with these unexpected events.

The research in this paper investigates how decisions are made in practice regarding managing these deviations. A project-as-practice approach has been used for studying practice on a micro-level in a project and to capture contextual circumstances.

Results show how these practices correspond to four different consequences of decisions and reveal the decision strategy used to manage the deviation. The characteristic of the decision-making process is described using the Garbage-Can model in order to highlight distinctive features of managing deviations.

## DECISION-MAKING IN DISRUPTIVE INNOVATION PROJECTS: A VALUE APPROACH

**Petetin, François; Bertoluci, Gwenola; Bocquet, Jean-Claude**

*Ecole Centrale Paris, France*

Disruptive technological innovation projects are very challenging for small firms, especially in industrial sectors with very high reliability expectations. Will the innovation create enough value to make up for the evolutions a firm needs to implement in order to successfully develop an innovation and the technological and market uncertainties? In this article we present an approach that aims to facilitate decision-making in disruptive technological innovation projects. It advocates using potential value creation for the stakeholder of the innovation and risks threatening this value creation as criterions during the decision-making process.

## INFLUENCE OF DESIGN EVALUATIONS ON DECISION-MAKING AND FEEDBACK DURING CONCEPT DEVELOPMENT

**Marini, Vinicius Kaster; Ahmed-Kristensen, Saeema; Restrepo, John**

*Technical University of Denmark, Denmark*

This paper aims to understand the following issues: how design flaws are diagnosed; how they influence feedback; and, how these matters could be improved in early design stages. A longitudinal, descriptive case study was carried out, following design alternatives generated over two and a half years, with the following results: evaluation methods are less than often carried out during conceptual design; failure modes motivating design decisions were repeated over time; and, feedback on robustness and reliability issues is generic when not absent. Recommendations were given to capture designers' preference and insight while they are designing to address robustness and reliability in early stages, and to use this knowledge in order to support these attributes by proposing countermeasures.

## DESIGN SUPPORT TOOLS FOR PRODUCT-SERVICE SYSTEMS

**Kim, Yong Se; Lee, Sang Won; Lee, Jee-Hyong; Han, Dae Man; Lee, Hye Kyung**

*Creative Design Institute, Sungkyunkwan University, Korea, South (Republic of)*

This paper discusses design support tools for product-service systems (PSS). During PSS design process comprising six phases such as requirement identification and value targeting, stakeholder activity design, PSS function modelling, function-activity mapping and PSS concept generation, PSS concept detailing and PSS concept prototyping, various design methods are used and many associated design information should be properly handled. Therefore, in this paper, the design support tools such as PSS DesignScape, life-cycle step modeling, stakeholder modelling, requirement modelling, PSS scenario generation, activity modelling, PSS function modelling, modified service blueprint and PSS representation are described. Sample case study is also conducted to demonstrate the effectiveness of developed design support tools for PSS.

# Managing Design Changes and Alternatives

Theme: Design Methods and Tools  
Chair: Pavkovic, Neven

## REDUNDANCY ELIMINATIONS AND PLAUSIBLE ASSUMPTIONS OF DESIGN PARAMETERS FOR EVALUATING DESIGN ALTERNATIVES

**Dentsoras, Argyris; Zapaniotis, Alexandros**

*University of Patras, Greece*

Evaluation of design alternatives is an important task for engineering design and its results affect strongly the outcome of decision-making processes and the quality of the artifact being designed. In the present paper, a method is proposed based on representation of alternatives through associative weighted digraphs of design parameters and use of performance variables defined according to evaluation criteria. The method relies on designer-guided eliminations of redundancies of common design parameters among different alternatives and plausible assumptions about value domains of design parameters that take part in the evaluation process. Eliminations of redundancies of common design parameters lead to unified digraphs for all alternatives and the introduction of Plausible Assumptions' Matrix systematizes the process of assigning feasible value domains for all types of all design parameters. Linear approximate calculation formulas pertaining to the unified digraphs are also introduced for evaluating alternatives based on comparable values of performance variables. A case study for two alternatives for a stiffness element exemplifies the proposed approach.

## MULTILAYER NETWORK MODEL FOR ANALYSIS AND MANAGEMENT OF CHANGE PROPAGATION

**Pasqual, Michael C.; de Weck, Olivier L.**

*Massachusetts Institute of Technology, United States of America*

A pervasive problem for engineering change management is the phenomenon of change propagation. This paper introduces a multilayer network model integrating three layers of product development that contribute to change propagation: namely, the product, change (process), and social layers. A baseline repository of tools and metrics is developed for the analysis and management of change propagation using the model. The repository includes a few novel tools and metrics, most notably the Engineer Change Propagation Index (Engineer-CPI) and Propagation Directness (PD), as well as others already existing in the literature. A case study of a large technical program is employed to demonstrate the model's practical utility. The case study discovers a correspondence between the propagation effects of an engineer's work and factors such as his/her organizational role and the context of his/her assignments. The study also confirms the counterintuitive possibility of indirect propagation between nonadjacent product components. Lastly, the study finds that propagation was generally infrequent and always stopped after five, and rarely more than four, generations of descendants.

## CHANGE IN REQUIREMENTS DURING THE DESIGN PROCESS

**Sudin, Mohd Nizam; Ahmed-Kristensen, Saeema**

*Technical University of Denmark, Denmark*

Specification is an integral part of the product development process. Frequently, more than a single version of a specification is produced due to changes in requirements. These changes are often necessary to ensure the scope of the design problem is as clear as possible. However, the negative effects of such changes include an increase in lead-time and cost. Thus, support to mitigate change in requirements is essential. A thorough understanding of the nature of changes in requirements is essential before a method or tool to mitigate these changes can be proposed. Therefore, a case study approach was employed to understand change in requirements - particularly concerning the initiation and management of these changes. Semi-structured interviews were adopted as the data collection method. The interviews were transcribed and analysed based on a pre-defined coding scheme. The results of the study shows that change in requirement was a normal part in the design process because internal stakeholders initiate changes through analysis and evaluation activities. In addition it was found that design engineers frequently updating specification document at the end of the design process

## BENCHMARKING STUDY OF AUTOMOTIVE SEAT TRACK SENSITIVITY TO MANUFACTURING VARIATION

**Mazur, Maciej (1); Leary, Martin (1); Huang, Sunan (1); Aleksandar, Subic (1); Baxter, Tony (2)**

*1: RMIT University, Australia; 2: Futuris Automotive Interiors Pty Ltd, Australia*

A benchmarking study is presented on the performance of automotive seat track profiles according to their sensitivity to manufacturing variation. Variation in rail geometry affects the elastic track preload and consequently the rolling effort of the track assembly. Rolling effort must be precisely controlled to achieve customer performance targets. Two benchmarking parameters are relevant to rolling effort: variation in bearing clearance and variation in bearing contact force. These were assessed using worse-case tolerance analysis of CAD data, and numerical analysis, respectively. Significant variation in performance was identified for the selected track profiles, which include commercially available designs and proposed concepts. The benchmarking approach demonstrated in this work provides a way of rapidly assessing the relative robustness of automotive seat track designs subject to manufacturing variation. The outcome assists automotive manufacturers to apply a systematic approach to automotive seat design based on a robust design evaluation of alternative embodiments.

APPROACH FOR THE CREATION OF MECHATRONIC SYSTEM MODELS

Follmer, Martin (1); Hehenberger, Peter (1); Punz, Stefan (1); Rosen, Roland (2); Zeman, Klaus (1)

1: Johannes Kepler University, Austria; 2: Siemens AG Corporate Technology

One of the major challenges in developing mechatronic products is the increasing complexity of the products themselves. The defining feature of mechatronic products is the interplay between various engineering disciplines such as mechanics, electronics, and software. There is a critical lack of methods and tools supporting the interdisciplinary aspects of the development process of mechatronic products, especially in the conceptual design phase. These deficiencies make it difficult to overview the interdependencies of the involved engineering disciplines. Mechatronic System Models (MSM) can improve this unsatisfactory situation and allow for a holistic view on complex mechatronic systems. MSM should at least be able to manage existing data and to illustrate the most important relations. Additionally, they should provide the possibility to execute several simulations of load cases, thus allowing specific “global” system properties to be evaluated. Typically these simulations at the system-level differ from those at the discipline-level.

EQUILIBRIUM DESIGN PROBLEMS IN COMPLEX SYSTEMS REALIZATION

Panchal, Jitesh

Washington State University, United States of America

We present a class of problems within engineering design where the design of complex systems is not directly controlled by designers but emerges from the self-interested decisions of stakeholders. These problems are referred to as equilibrium design problems. While such problems have been common in economics and social sciences, they have not yet been addressed in engineering design research. This is because the focus in engineering design is on technical performance with the assumption that designers directly control the design space. However, with the increasingly interconnected nature of the technical, social, economic and environmental aspects, equilibrium design problems become more important for designers. Instead of solving a specific equilibrium design problem, the goals in this paper are to highlight the importance and uniqueness of this class of problems and to present a general formulation within the context of engineering design. Specifically, we present a general formulation by using concepts from non-cooperative game theory, mathematical tools for solving them, and various examples of problems relevant to engineering design that can be modeled as equilibrium design problems.

IMPROVING DATA QUALITY IN DSM MODELLING: A STRUCTURAL COMPARISON APPROACH

Schmitz, Steffen (2); Wynn, David (1); Biedermann, Wieland (2); Lindemann, Udo (2); Clarkson, John (1)

1: University of Cambridge; 2: Technische Universität München

The Dependency Structure Matrix (DSM) has proved to be a useful tool for system structure elicitation and analysis. However, as with any modelling approach, the insights gained from analysis are limited by the quality and correctness of input information. This paper explores how the quality of data in a DSM can be enhanced by elicitation methods which include comparison of information acquired from different perspectives and levels of abstraction. The approach is based on comparison of dependencies according to their structural importance. It is illustrated through two case studies: creation of a DSM showing the spatial connections between elements in a product, and a DSM capturing information flows in an organisation. We conclude that considering structural criteria can lead to improved data quality in DSM models, although further research is required to fully explore the benefits and limitations of our proposed approach.

DESIGNING CONSISTENT STRUCTURAL ANALYSIS SCENARIOS

Biedermann, Wieland; Lindemann, Udo

Technische Universität München, Germany

Companies face challenges due to rising complexity through shorter market lifecycles, manifold costumer requirements, additional solutions options and discipline-spanning cooperation. Efficient tools for analyzing and assessing solutions and processes are necessary during the development. Structural considerations are an established approach, which can be used in early phases of the innovation process. Manifold structural analysis criteria such as cycles and clusters are applicable in complexity management. The criteria are interconnected. Their interrelations cause redundant analyses. Developers must choose appropriate criteria combinations to gain significant results efficiently. Researchers have to develop consistent, non-redundant structural analysis scenarios. In this paper we present a model of the interrelations of structural analysis criteria. We propose a procedure for the development of structural analysis scenarios and show its application in one case study. Researchers get a tool for the systematic creation of structural analysis scenarios. Industrial applicators get efficient tools for structural complexity management.

HOW IMPORTANT IS TEAM STRUCTURE TO TEAM PERFORMANCE?

Singh, Vishal (1); Dong, Andy (2); Gero, John S (3)

1: Deakin University, Australia; 2: The University of Sydney, Australia; 3: Krasnow Institute for Advanced Study, Virginia, USA

This paper discusses the effects of team structure on the performance of design teams. Three types of team structures are differentiated on the basis of the functional and social groups that result from task dependencies and interaction opportunities. The reported findings are based upon results from simulation-based studies using a computational model. Differences across the team structures are investigated through a series of simulations in which the team membership and the workload busyness of the team members are independent variables, and the team performance and formation of team mental models are the dependent variables. Team performance is measured in terms of the ability of the team members to coordinate the set of tasks the team needs to perform. Findings suggest that, in general, flat teams facilitate formation of team mental models, while functional teams are best for efficient task coordination.

ADOPTION OF A SYSTEMATIC DESIGN PROCESS: A STUDY OF COGNITIVE AND SOCIAL INFLUENCES ON DESIGN

Morgan, Thea; Tryfonas, Theo

University of Bristol, United Kingdom

This paper presents an ethnographic case study of an engineering design team during the development and implementation of a systematic design process. Prior to this the team had used only adhoc and informal design strategies. The team was observed for 12 months after implementation of the new process, during which time two subsequent versions of the design process were developed and released in response to observations and team feedback. The findings of this study highlight the way in which cognitive and social factors may have a strong influence on the design process in teams, and should therefore be given greater consideration in the future development of design methods and processes as well as in design education.

CULTURE AND CONCEPT DESIGN: A STUDY OF INTERNATIONAL TEAMS

Wodehouse, Andrew J (1); Maclachlan, Ross (1); Grierson, Hilary J (1); Strong, David (2)

1: University of Strathclyde, United Kingdom; 2: Queen's University, Canada

This paper explores the relationship between culture and performance in concept design. Economic globalisation has meant that the management of global teams has become of strategic importance in product development. Cultural diversity is a key factor in such teams, and this work seeks to better understand the effect this can have on two key aspects of the concept design process: concept generation and concept selection. To this end, a group of 32 students from 17 countries all over the world were divided into culturally diverse teams and asked to perform a short design exercise. A version of the Gallery Method allowed two kinds of activity to be monitored – the individual development of concepts and the collective filtering and selection of them. The effect of culture on these processes was the focus of the work. Using Hofstede's cultural dimensions, the output from the sessions were reviewed according to national boundaries. The results indicate that individualism and masculinity had the most discernable effect on concept generation and concept selection respectively.



CREATIVE TEAMWORK IN QUICK PROJECTS DEVELOPMENT QPD, 24 HOURS OF INNOVATION

Jiménez-Narvaez, Luz-Maria (1); Choulier, Denis (2); Legadeur, Jeremy (3); Gardoni, Mickael (4)

1: École de Technologie Supérieure ÉTS Montréal, Canada; 2: Université de Technologie de Belfort-Montbéliard, France; 3: École Supérieure des Technologies Industrielles Avancées, ESTIA France; 4: École de Technologie Supérieure ÉTS Montréal, Canada

In this paper, we are interested in the analysis of the creative activity of charrettes of innovation in product design. The charettes are “an intensive, concentrated and deadline oriented group confrontation and discussion technique” [1]. We consider that our research could clarify four discussion topics regarding creative teamwork in charrettes in the particular context of 24h charettes duration: a) team building and the idea development into the 24h, b) an analysis of the issues presented in the innovative projects and the response of the team, c) the use of time in work sessions and d) the role of the leader in the team creative performance. These answers are important for the planning of teamwork in the QPD activities of technological projects. This empirical study was carried out within the context of the Fourth Edition of the 24 Hours (24H) of Innovation international competition, organized by the École Supérieure des Technologies Industrielles Avancées (ESTIA, France), with the participation of almost 250 university students coming from 25 different universities and in partnership with more than 30 industrial enterprises and with École de Technologie Supérieure (ÉTS, Canada) as a partner.



INTRODUCTION

The Design Society holds its General Meetings every two years during the ICED conferences. At these Meetings the activities of the Society are presented, discussed and, if required, voted upon. Elections to the Society's Board of Management and Advisory Board also take place at (or by the time of) the General Meeting. This year the Meeting is especially important as it is the first for the Society under its new legal status of a "Company Limited by Guarantee" – an arrangement used in British law for non-profit organisations that require legal status and limited liability for their members. The Agenda will include provision for reports on the membership and financial status of the Society, on the activities that have taken place since the last meeting in Stanford and on plans for future development. The meeting is also the opportunity for the Society to bestow honours on those members of the community that have contributed most strongly to the promotion of design research and the Society's aims.

The Agenda and arrangements for elections will have been sent to all members by email before the Conference and will also be available for perusal during the Conference at the Design Society stand. All members of the Society are very strongly encouraged to attend the Meeting, but a member who is unable to attend the Meeting may, by informing the President in writing, constitute another member participating in the Meeting as proxy. Please leave any notice of proxy at the Design Society stand or contact the President by email at [president@designsociety.org](mailto:president@designsociety.org)

LOGISTICS

Due to the time constraints the conference organisers have arranged for shuttle busses to take the Design Society Members attending the General Meeting directly to the starting point for the gala dinner.

Please note that there will not be enough time to return to your hotel before the meeting so please arrive at the conference venue on Wednesday morning with this in mind.

Following the general meeting please board the shuttle busses waiting outside of the main entrance without delay.



INTRODUCTION

The evening commences with a boat trip along the canals and harbour of Copenhagen (embarking at 18:30, Nyhavn/Havnegade - see map, below and p179).

Located on the waterfront and with unrivalled views of The Little Mermaid, the restaurant, Langelinie Pavillonen, contains some of the finest examples of 1950s Danish design, including Poul Henningsen's world-famous cone lamps, of which the restaurant is the proud owner of the first eight ever produced. With its superb cuisine, the evening is bound to be a great experience!

Langelinie Pavillonen was designed in 1954 by architects Eva and Nils Koppel, who also designed DTU's Lyngby campus!

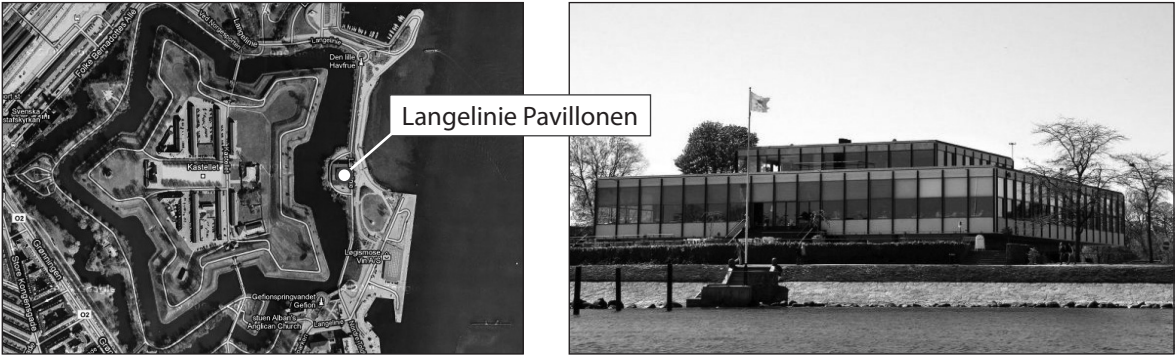
PRACTICAL INFORMATION

- Despite the fine title, Gala Dinner, dress code is casual – you should feel comfortable and relaxed.
- The boat trip takes approximately 30 minutes. If you would prefer to meet us directly at Langelinie Pavillonen, then we recommend that you arrive at the address below, by 19:30, in time for the welcome drink.
- The evening will consist of a served starter, followed by a buffet. Your dietary requirements have been recorded when you registered for the conference. Any further requirements should be communicated to the ICED11 Registration Desk on Monday or Tuesday (15-16 August).
- There will be light entertainment during the dinner and a band after dessert – bring your dancing shoes if you like!
- The Gala Dinner will close at 23:00, after which the city is open for adventure ... or maybe a well deserved sleep!

LOGISTICS

**Non DS-members:** Wednesday's parallel conference sessions close at 15:45. This gives you ample time to take a regular route bus (the yellow buses – see a list of bus routes on p179) back to the city, freshen up and meet in Nyhavn at **18:30**.

**DS-members:** As the DS General Meeting will be held at DTU from 16:00 - 17:15, we have arranged for the shuttle busses to collect you from DTU, immediately after the DSGM and take you directly to Nyhavn for the boat trip. Those of you with accompanying partners/family should arrange to meet them at Nyhavn, around 18:15.



Langelinie Pavillonen  
Langelinie 10  
2100 Copenhagen  
T: +45 3312 1214

	D	Discussion Sessions	P	Podium Sessions	W	Workshop Sessions
08:30 - 10:00	Optimal Systems Room: Discussion Room 1 Theme: Product and Systems Design	p146 Managing Through Life Risk Room: Discussion Room 2 Theme: Design Methods and Tools	p148 Objects and Contexts Room: Discussion Room 5 Theme: Human Behaviour in Design	p150 Sustainability and Life-Cycle Room: Podium Room s01 Theme: Theory and Research Methodology	p152 Robust and Optimal Design Room: Podium Room s09 Theme: Design Methods and Tools	p143 Design Creativity SIG Workshop: Creativity in Design Room: Workshop Room s08
10:00 - 10:30	Break					p144 Structural Complexity SIG Workshop: Creation of a Benchmark Pool Room: Workshop Room s16
10:30 - 11:50	Managing and Improving the NPD Process Room: Discussion Room 1 Theme: Design Organisation & Management	p154 Customer/End-User Information Room: Discussion Room 2 Theme: Design Information and Knowledge	p156 Methods and Tools for Sustainable Design - II Room: Discussion Room 5 Theme: Design for X, Design to X	p158 Process Modelling Room: Podium Room s01 Theme: Design Processes	p160 Decision Support and Decision Making Room: Podium Room s09 Theme: Design Methods and Tools	p145 Design Education SIG Workshop: Current Issues in Design Education Room: Workshop Room s06
12:00 - 12:30	Eco-Design Keynote: New Standards for Industrial Motor Efficiency Mads Sckerl, Grundfos Main Hall					p162
12:30 - 13:00	Complexity Keynote: Designing Complex Systems for the 21st Century Wei Chen, Northwestern University Main Hall					p163
13:00 - 14:15	Lunch			Design Society AB Meeting Room: Workshop Room s08	IPD Workshop Meeting Room: Workshop Room s16	p81
14:15 - 15:45	Educational Approaches and Industry Room: Discussion Room 1 Theme: Design Education	p164 Lean Thinking Room: Discussion Room 2 Theme: Design Processes	p166 Virtual Prototyping Room: Discussion Room 5 Theme: Design Methods and Tools	p168 Research Methods Room: Podium Room s01 Theme: Human Behaviour in Design	p170 Tool Applications Room: Podium Room s09 Theme: Design for X, Design to X	p171 Systems Modelling Room: Podium Room s02-03 Theme: Product and Systems Design
15:55 - 16:25	Design Methodology Keynote: Reflections in Context of Design Research History Mogens Myrup Andreassen (DTU); Ken Wallace (University of Cambridge) Main Hall					p173
16:25 - 17:00	Closing Ceremony Main Hall					
17:00 - 18:30	Closing Reception Garden Area at the Conference Venue					p18

CREATIVITY IN DESIGN

Chairs: Toshiharu Taura (Kobe University) and Yukari Nagai (JAIST)

Workshop Theme

Creativity is an important and interesting topic of study in design. This workshop aims to create a forum to discuss the nature and potential of design creativity from theoretical and methodological viewpoints. In particular, the workshop focuses on the theme of “Bases for Design Creativity Research.” This workshop is the beginning of a series of three discussions that will be held at ICED11, DESIGN 2012 in Croatia, and ICDC 2012 in Glasgow. Its theme is intended to establish a historical, theoretical, educational, and practical foundation for design creativity research.

Workshop Programme

The workshop consists of two sessions:

- First Session: Panel Discussion: Bases for Design Creativity Research  
Moderator: Dr.Alex Duffy  
Panelists: Dr.Armand Hatchuel, Dr.Rivka Oxman, Dr.Yukari Nagai
- Second Session: Group Discussion  
A group discussion on some subtopics of the main theme and an open discussion will be held for all the attendees.  
Commentator: Dr.John Gero

Position Papers

Attendees are encouraged to submit position papers (due August 1, 2011, 2 page limit, A4 size, no specified format) on the workshop theme to the SIG Secretariat (design@jaist.ac.jp). The position papers will be handed out at the workshop in a stapled format and will be used as a reference during the group discussion.

Detailed Information

Detailed information will be provided at the SIG webpage (<http://www.jaist.ac.jp/ks/labs/nagai/DesignCreativityW/>).

CREATION OF A BENCHMARK POOL

Chairs: Udo Lindemann (TU München) and Maik Maurer (TU München)

Situation & problem

The importance of structural complexity in engineering design can be seen by applications like product modularization or change management. Most research work concentrates on analysis and optimization of system structures. For example, many clustering algorithms exist for product modularization. Today, acquisition of system structures is not a research focus. However, quality of information acquisition affects possibilities of analysis and optimization.

Approaches on analysis and optimization of system structures mostly apply published or self created test structures. Published structures are often unsuitable for the specific context. And application of e.g. a cluster algorithm on self created structures impedes comparison with other algorithms. Whereas standard tests exist e.g. for genetic algorithms, applications in the field of structural complexity can not be benchmarked so far.

Objective (2 year period)

The SIG develops benchmarks for testing and comparing approaches in the field of structural complexity. Benchmarks are classified by the application context (software, product etc) or optimization objectives (minimum process time etc).

The benchmark pool requires adaptations over time. The SIG sets up a process for proposing, approving and implementing these adaptations. Not only benchmark structures, but also analysis/optimization results shall be provided. This allows comparing different approaches.

Objective (ICED11-workshop)

The success of the benchmark pool depends on the researchers' acceptance. We collect the requirements on content, process and functionality of the benchmark pool. The workshop result will be the specifications for future work.

Agenda for ICED11

- Introduction: Test cases, use cases and examples applied in Structural Complexity Management
- Benchmark pool: As-is conception and partners
- Acquisition of requirements: What do researchers expect from a benchmark pool for applications of Structural Complexity Management?

CURRENT ISSUES IN DESIGN EDUCATION

Chair: William Ion (University of Strathclyde)

Workshop Objectives

The workshop aims to explore two topical issues within engineering design education, namely, Open Ended Resources (OERs) in design education and the role of Systems Design in design education. Each topic will be introduced by a short presentation on current activity in the field and will then be followed by a discussion around predefined issues. The workshop will conclude with the generation of a set of conclusions and recommendations for use by design educators.

Workshop Agenda

08:30 Introduction to workshop objectives and participants

08:40 Open Educational Resources (OER) in Design Education

This section will commence with a presentation of the concept of open educational resources (OERs) and an overview of their availability in design. It will also present computer-based resources to assist in the search for OERs. Discussion will centre on the needs for OERs in design, the gaps in the coverage of available resources and an assessment of the suitability of the presented search tools.

Presented and facilitated by: Professor Chris McMahon

10:00 Coffee

10:30 Integrated Systems Design (ISD) in Design Education

This topic will begin with a presentation on the principles of ISD and the need to embed systems thinking approaches to design at undergraduate level education. This will be followed by a discussion on the ISD education practices of current undergraduate courses and the need to provide industry with graduates who have experience of systems thinking. Discussions will also centre on the key mechanisms to embed ISD within existing course modules that are often predominantly focused on component or product design.

Presented and facilitated by: Dr Alastair Conway

11:40 Summing up/Conclusion



EMPIRICAL CONSIDERATION OF PREDICTING CHAIN FAILURE MODES IN PRODUCT STRUCTURES DURING DESIGN REVIEW PROCESS

Otsuka, Yuichi (1); Takiguchi, Sho (1); Shimizu, Hirokazu (2); Mutoh, Yoshiharu (1)

1: Nagaoka University of Technology, Japan; 2: Toyota motors, Japan

The DRBFM (Design Review Based on Failure Mode) method has been proposed for predicting latent failures in design stages. The errors in conducting the DRBFM method can be classified into three types; the error of unnoticed, the error of underestimating and the error of misunderstanding. This paper describes the modified DRBFM to effectively find the errors of underestimating. In the modified DRBFM method, a root of failures in a network of failures can be specified from the differences in design features between current products and previous reliable one. Updating the preconditions of functions changed by the failures in relating elements can visualize the newly generated changes that can provoke chained failures. To compare the performances of detecting latent errors of underestimating, 28 mechanical engineering students conducted the conventional FMEA or the modified DRBFM method by themselves. The result significantly showed that the modified DRBFM method is more effective in detecting failures which causes the errors of underestimating.

ANALYSING MODIFICATIONS IN THE SYNTHESIS OF MULTIPLE STATE MECHANICAL DEVICES USING CONFIGURATION SPACE AND TOPOLOGY GRAPHS

Todeti, Somasekhara Rao; Chakrabarti, Amaresh

Indian Institute of Science, Bangalore, India, India

Automated synthesis of mechanical designs is an important step towards the development of an intelligent CAD system. Research into methods for supporting conceptual design using automated synthesis has attracted much attention in the past decades. In our research, ten experimental studies are conducted to find out how designers synthesize solution concepts for multi-state mechanical devices. The designers are asked to think aloud, while carrying out the synthesis. These design synthesis processes are video recorded. It has been found that modification of kinematic pairs and mechanisms is the major activity carried out by all the designers. This paper presents an analysis of these synthesis processes using configuration space and topology graph to identify and classify the types of modifications that take place. Understanding of these modification processes and the context in which they happened is crucial to develop a system for supporting design synthesis of multiple state mechanical devices that is capable of creating a comprehensive variety of solution alternatives.

THE PROCESS OF OPTIMIZING MECHANICAL SOUND QUALITY IN PRODUCT DESIGN

Nielsen, Thomas Holst; Eriksen, Kaare Riise

Aalborg University, Denmark

The research field concerning optimizing product sound quality is a relatively unexplored area, and may become difficult for designers to operate in. In some degree, sound is a highly subjective parameter, which is normally targeted sound specialists. This paper describes the theoretical and practical background of managing a process of optimizing the mechanical sound quality in a product design by using simple tools and workshops systematically. The procedure is illustrated by exploring a case study regarding a computer navigation tool (computer mouse or mouse). The process is divided into 4 phases, which clarify the importance of product sound, defining perceptive demands identified by users, and, finally, how to suggest mechanical principles for modification of an existing sound design. The optimized mechanical sound design is followed by tests on users of the product in its use context. The result of this article is a systematic process, which has the possibility of enhancing the knowledge about sound design in products and its cause and effect.

PRODUCT MODEL OF THE AUTOGENETIC DESIGN THEORY

Kittel, Konstantin (1); Vajna, Sándor (1); Hehenberger, Peter (2); Zeman, Klaus (2)

1: Otto-von-Guericke University Magdeburg, Germany; 2: Johannes Kepler University Linz, Austria

Product development plays the key role in defining all product properties and benefits. There is a need for appropriate supporting methods that are able to serve and to satisfy multi-criteria and multi-domain requirements. These requirements usually go beyond function fulfilment. Developing mechatronical systems raises the requirements for the applied product development methods, because of the high number of linked elements from different technical und physical domains. Integrating and combining solutions from different domains does not only increase the number of possible solutions, but also the complexity of such systems. Product development methods need to be able to handle these requirements appropriately in order to support the designer within the product development process.

PARETO BI-CRITERION OPTIMIZATION FOR SYSTEM SIZING : A DETERMINISTIC AND CONSTRAINT BASED APPROACH

Yvars, Pierre-Alain

Institut Supérieur de Mécanique de Paris (SupMeca), France

In this paper we are studying a deterministic constraint based approach to solve Pareto bi-criterion optimization problems in design. After presenting a state of the art of multi-objective optimization methods in design, the CSP method and the several ways to solve it is introduced. A quick overview of CSP application in product engineering is given too. Moreover, we introduce an optimization point of view for CSP and we propose a deterministic alternative to stochastic methods for solving Pareto bi-objective system sizing problems. An example in mechanical system optimization is given via the case study of the Pareto bi-criterion optimal design of a bolt coupling. The case is modeled as a Constraint Satisfaction Problem on both discrete and real variables. Finally, the numerical results and the Pareto frontier are exposed.

# Managing Through-Life Risk

Theme: Design Methods and Tools  
Chair: Cagan, Jonathan

## EVALUATING THE RISK OF CHANGE PROPAGATION

**Oduncuoglu, Arman; Thomson, Vince**

*Department of Mechanical Engineering, McGill University, Canada*

The ever changing trends in current markets along with customers’ rising demands for quality require many companies to continuously develop new products. Many companies use iterative design to add new features to old products. The changes from the iterative approach along with the usual changes demanded by customers and made by engineers have created a difficult environment to manage. In this environment, many changes drive other changes in the product. This paper develops a technique to evaluate the risk of change propagation by using functional analysis, domain mapping matrix (DMM), and component design structure matrix (C-DSM) methods. This technique obtains the change propagation risk for a conceptual design solution at a functional level and provides insight for future resource requirements (i.e., development effort, product cost, etc.). The objective of the technique is to increase product knowledge in the early stages of design, to provide insight on the effects of engineering change, and to support design engineers in decision making.

## EARLY RELIABILITY ESTIMATION IN AUTOMOTIVE INDUSTRY

**Kopp, Michael (1); Hofmann, Daniel (1); Bertsche, Bernd (1); Heß, Christian (2); Fritz, Oliver (2)**

*1: Universitaet Stuttgart, Germany; 2: Daimler AG, Germany*

Increasing functional requirements and system complexity on the one hand and decreasing time for development as well as cost reduction on the other hand are some of the challenging constraints that car manufacturers face today. Additionally, customers expect high quality products. To meet these challenges, a quantitative reliability estimation method, which can be connected with established methods, is necessary even in early development phases. The present paper illustrates a method for early quantitative reliability prediction of mechatronic systems such as in automotive engineering. The core of this method is to support a reliability-oriented system development. the method allows to show and quantify weak spots for systems’ reliability. Therefore, existing qualitative and quantitative data is used, for example expert information or warranty data. Hence, new and innovative components with no existing data can be handled. After all, criticality analysis and reliability optimization is facilitated. To demonstrate the features of the method, a typical automotive system of a car power window regulator is illustrated.

## UNDERSTANDING ADAPTABILITY THROUGH LAYER DEPENDENCIES

**Schmidt III, Robert; Deamer, Jason; Austin, Simon**

*Loughborough University, United Kingdom*

This paper looks at change from the perspective of building design (i.e. adaptability), and how a better understanding of product architecture can bring about an easier accommodation of change for an unforeseeable future. The work explores the use of a design structure matrix (DSM) to understand the building’s capacity to accommodate change using building decomposition methods and component interactions as initial guides to suggest possible product architectures. Research for this study took place along side the design stage of an ongoing BSF school project. The systematic analysis of design drawings and reports was undertaken in three phases: code documents using Brand’s layers; identify all variant components to create a work breakdown structure; and classification of all component relationships populating a DSM. Insights that have been gained through the data include the appropriate layer placement of components, the possibilities of new/ different layers, and the highlighting of unwanted/ hidden dependencies. The DSM permutations have also prompted the development of component typologies in an effort to provide a consistent, logical approach to refining the matrix.

## CAN DESIGNERS BE PROACTIVELY SUPPORTED AS FROM PRODUCT SPECIFICATIONS?

**Galea, Amanda; Borg, Jonathan; Grech, Alexia; Farrugia, Philip**

*University of Malta, Malta*

During the design process, designers are concerned with two main types of issues - issues related to “what needs to be achieved” or “whats” and issues related to “how these needs will be met” or “hows”. A literature review carried out revealed that means which proactively make designers aware of artefact life-cycle consequences (LCCs) arising from both their “whats” and “hows” and which guide them on how to minimise or avoid any negative consequences, are lacking. This research thus contributes an approach framework to meet this aim. The approach framework developed is further implemented as a prototype computer-based tool and subsequently evaluated. Based on the feedback obtained from the evaluation, future research directions are also proposed.

## UNDERSTANDING MANAGERS DECISION MAKING PROCESS FOR TOOLS SELECTION IN THE CORE FRONT END OF INNOVATION

**Appio, Francesco Paolo (1); Achiche, Sofiane (2); McAloone, Tim C. (2); Di Minin, Alberto (1)**

*1: Scuola Superiore Sant’Anna, Italy; 2: Technical University of Denmark, Denmark*

New product development (NPD) describes the process of bringing a new product or service to the market. The Fuzzy Front End (FFE) of Innovation is the term describing the activities happening before the product development phase of NPD. In the FFE of innovation, several tools are used to facilitate and optimise the activities. To select these tools, managers of the product development team have to use several premises to decide upon which tool is more appropriate to which activity. This paper proposes an approach to model the decision making process of the managers. The results underline the dimensions influencing the decision process before a certain tool is chosen, and how those tools impact the performance of cost, time and efficiency. In order to achieve this, five companies participated for the data collection. Interesting trends and differences emerge from the analysis of the data in hand, and several hypotheses are tested. A preliminary version of a theoretical model depicting the decision process of managers during tools selection in the FFE is proposed. The theoretical model is built from the constructed hypotheses.

## AN EXAMINATION OF THE APPLICATION OF PLAN-DO-CHECK-ACT CYCLE IN PRODUCT DEVELOPMENT

**Lodgaard, Eirin; Aasland, Knut Einar**

*Norwegian University of Science and Technology, Norway*

Plan-Do-Check-Act (PDCA) cycle is a high level methodology for achieving continuous improvement that has been a basic element of the total quality management movement. It is a practical tool and is widely adopted in the automotive sector as an improvement tool to managing improvement projects especially within manufacturing. The aim of this paper is to evaluate how the continuous improvement processes are conducted compared to the PDCA cycle and to better understand the improvement processes in a PD environment. The results from the case study shows that the PDCA cycle is not always followed precisely according to the formally described quality assurance system in the companies. Nevertheless, the case companies emphasizes that they naturally, as engineers, do improvements every day. The companies have according to our evaluations never given the PDCA method a proper chance to prove its usefulness in PD. Consequently, the companies claim that the method will be most suitable when the problem to be analyzed is sufficiently complex, when there are no time constraints and enough resources to spend on the problem.

UNDERSTANDING THE CONTEXTS OF THE FRONT END OF DESIGN

Harrison, Thomas; Marco, Aurisicchio  
Imperial College London, United Kingdom

What do we really know about design experience during the front end of design and which personality traits assist the designer? This paper describes empirical research currently taking place into understanding the knowledge, skills and traits that are utilised by the designer during the early part of new product development (NPD). A literature review of papers that refers to knowledge, skills and traits being used during NPD and creative activities is presented. The knowledge, skills and traits discussed by designers of varying levels of experience during interviews with the main author of the article are then compared to findings from the literature review.

THE RELATIONSHIP BETWEEN A MODEL AND A FULL-SIZE OBJECT OR BUILDING: THE PERCEPTION AND INTERPRETATION OF MODELS

Eriksson, Yvonne; Florin, Ulrika  
Mälardalen University, Sweden

There is a naive belief in models as a blueprint for objects and environments that goes back to the epistemology of The Enlightenment. In the manufacturing industry and in society, many decisions concerning new products or urban planning are based on models representing the actual object or area. Substantial experience is required to interpret models, especially when it comes to the effect different scales have on material, colors and volume. This paper will address theoretical aspects of our ability to interpret and understand the relationship between 3D-models on computer screens or constructions of models and the object in full scale.

ENABLING OBJECTS FOR PARTICIPATORY DESIGN OF SOCIO-TECHNICAL SYSTEMS

Broberg, Ole  
Technical University of Denmark, Denmark

The aim of this paper is to identify and explore the role of objects in participatory ergonomics design processes. The question in focus is: What characterizes objects in PE processes? First the concept of boundary objects is introduced as a starting point for investigating the role of objects. Second, findings of a search to identify objects in PE processes are reported. Third, objects fulfilling the requirements for boundary objects are placed in one of five categories. Fourth, empirical findings from two PE case studies in which objects played an important role are presented. Finally, based on a grounded theory approach, a characterization of objects in PE design processes is developed and a framework for how the use of objects in PE processes could be conceptualized is proposed. In conclusion, the concept of objects in PE processes is contextual, and the ergonomist or other design actor needs to actively consider their selection and the stage at which they are to be used.

A METHOD TO STUDY AFFECTIVE DYNAMICS AND PERFORMANCE IN ENGINEERING DESIGN TEAMS

Jung, Malte Friedrich; Leifer, Larry  
Stanford University, United States of America

The practice of designing in teams is a socially mediated activity. Team members interact with one another to generate and develop concepts and physical artifacts over time. Researchers explored many different aspects of design interactions in order to generate new insights and theory about how interaction characteristics and performance relate. Despite many years of research not much has been done to explore the role of emotions in the context of the relationship of interaction dynamics and performance. The authors attribute this lack of research mainly to a lack of appropriate research methods to study emotions. In this paper we show that methods developed to study emotions in marital interactions can be used to study emotions in design team interactions. We describe the key components of such a method and share insights gained from its application three cases.

IMPROVING COMMUNICATION IN DESIGN: RECOMMENDATIONS FROM THE LITERATURE

Maier, Anja M. (1); Doenmez, Denniz (2); Hepperle, Clemens (3); Kreimeyer, Matthias (4); Lindemann, Udo (3); Clarkson, P John (5)

1: Technical University of Denmark, Denmark; 2: Eidgenössische Technische Hochschule (ETH) Zurich, Switzerland; 3: Technische Universität München, Germany; 4: MAN Nutzfahrzeuge Gruppe, Germany; 5: University of Cambridge, UK  
Communication permeates every aspect of an engineer's work – from clarifying product specifications to shaping social ties. This paper offers an overview of recommendations from literature to improve communication within and among engineering teams. We assume communication problems are often the outcome of underlying factors and that it is fruitful to study and improve these influences. 24 factors considered in this paper, having been empirically elicited in prior research, include, e.g., availability of information about product specifications, roles and responsibilities, and overview of sequence of tasks. 120 recommendations to improve these factors in order to enable effective communication are collated from journal articles and textbooks published in the fields of engineering design, management science, sociology, and psychology. Recommendations include, for example, identify priorities through risk and bottleneck analysis, give clear descriptions and role expectations, and employ effective process modeling tools. Contributions of this paper are a list of recommendations for industry practitioners and an effort-benefit evaluation of individual recommendations.

INFORMATION BEHAVIOR IN MULTIDISCIPLINARY DESIGN TEAMS

Ensici, Ayhan (1); Badke-Schaub, Petra (2)  
1: Istanbul technical university, Turkey; 2: Delft University of Technology, Netherlands

A common challenge in business life is the need to compose multidisciplinary teams to foster efficiency and innovative thinking by using different expertise on a problem or project. The research area of this study is to analyze information dimensions that occur in multi-disciplinary design teams during their problem solving activity. In order to observe and record multidisciplinary information behavior of design team work, a design task in a laboratory environment has been set up. For in-depth understanding of the process the verbal transcripts have been analyzed and coded according to 'design content' and 'information behavior'. The data describe the information behavior through the design process and to define the flow of information within the process. The results gained from the frequency and duration analysis clearly state that using more information or dedicating bigger portion of time to information behavior do not help the team to come up with the desired outcome. The results of design content analysis provides a thorough understanding of the information flow based on the design content.



E3 VALUE CONCEPT FOR A NEW DESIGN PARADIGM

Kim, Yong Se (1); Cho, Chang K. (1); Ko, Young Dae (1); Jee, Haeseong (2)

1: Creative Design Institute, Sungkyunkwan University, Korea, South (Republic of); 2: Hong-Ik University, Korea

In this paper, the E3 value concept composed of economical, ecological, and experience values is proposed. Economical values include cost reduction and income enhancement which can be achieved by differentiation, market creation, customer acquisition and retention. Ecological values address the issues such as energy and water saving, dematerialization, reducing hazardous materials, reuse and recycling. Experience values deal with more people-oriented viewpoints including utilitarian and hedonic aspects. With the adoption of consumer value framework by Holbrook, extrinsic and intrinsic value dimension is used as the first classifier of experience value and other aspects of experience such as emotional, social, and epistemic are also considered. Also, emotional value can be specified into active and reactive emotional value with Scherer's classification of emotion. Lastly, we introduce briefly an example case to confirm and clarify the proposed E3 value concept.

INTEGRAL DESIGN: TO COMBINE ARCHITECTURE AND ENGINEERING FOR A SUSTAINABLE BUILT ENVIRONMENT

Zeiler, Wim

Technical University Eindhoven, Netherlands, The

The traditional way of designing in the Building Industry has to change to meet the new demands for a sustainable built environment by society. In order to enhance team design in the most crucial phase for innovation, the conceptual design phase, a design method is proposed: Integral Design. Integral design was developed from Methodical Design. This design method uses morphological charts which are transformed to a morphological overview by the design team as a framework to support the design process itself. The design method was tested in workshops held in cooperation with the Dutch Society of Architects and the Dutch society of building services engineers. It is important to bring in the specific knowledge and experience of the different engineering consultants (structural, building physics and building services) besides the architect from the very first moment of a design project to increase the possibilities for sustainable innovation. It proved that the design method applied in the workshops had a strong positive effect on the number of alternative generated by the design teams.

DESIGN INSPIRED INNOVATION FOR RURAL INDIA

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1: Mälardalen University, Sweden; 2: Munktell Science Park, Sweden; 3: Welingkar Institute of Management Development & Reserach, India

The need for reducing poverty and to develop the standard of living in rural areas around the world is enormous. Ideas for new approaches have to be implemented. Design thinking and methods combined with innovation in practice and management – as Design Inspired Innovation – could be such a concept to provide for rural people to empower themselves and improve their living conditions. The purpose of this paper is to present and discuss an initiative in India started between Swedish and Indian researchers, students and a network of other organizations. The initiative is based on a combination of appropriate design research methodology, ethnographic design research and innovation science and management. Some experiences from initial empirical studies show that master students gathering data in the field, analyzing and interpreting the data together with researchers can get new insights and rich knowledge of the opportunities of improvements, innovation and entrepreneurship that exists at the 'bottom of the pyramid'.



PRODUCT FAILURE: A LIFE CYCLE APPROACH

Del Frate, Luca

Delft University of Technology, Netherlands, The

The aim of this paper is to introduce a life cycle perspective on the notion of failure of engineered products. Usually failure is seen as an event that can occur during the utilization stage of products. Moreover, most definitions describe failure in terms of manifest termination of expected performance. The life cycle perspective expands this view by including failures occurring outside the utilization stage, and offers a categorization of phenomena that are arguably also taken as failures in engineering. The paper starts by considering previous attempts to take the life cycle into account when dealing with product failure. A definition of failure suitable for the life cycle approach is proposed and applied to categorize a number of case stories and examples of failure occurring in different stages of the life cycle, confirming the engineering credibility of the approach. Moreover, it shows that the life cycle approach affords applying the notion of failure to events that can occur after the products are removed from service and are related to their sustainability.

EARLY ROBUSTNESS OPTIMIZATION OF AUTOMOTIVE MODULES – REGARDING THE KEY IMPACT OF THE HUMAN FACTOR

Wuttke, Fabian (1,2); Feustel, Florian (1); Bohn, Martin (1); Csernak, Steffen (1); Bohn, Andrea (3)

1: Daimler AG, Germany; 2: Karlsruhe Institute for Technology, Germany; 3: Technische Universität Darmstadt, Germany

In the context of module based car development, standard modules face large uncertainties during their integration into the development process of the car. This leads to the need for a high robustness of standard modules. Therefore, a method is presented to optimize robustness on the technical side. In addition to the technical perspective, the human role is considered. This paper aims at identifying the demands of the method on designers as well as the designer's requirement on the method. The discrepancy between these two demands determines the robustness of the process. Hence, robustness is evaluated holistically, including both the technical and the process side considering the human factor.



A METHODOLOGY TO EVALUATE THE STRUCTURAL ROBUSTNESS OF PRODUCT CONCEPTS

Kissel, Maximilian; Hellenbrand, David; Lindemann, Udo

Technische Universität München, Germany

The success of a company is sustainably dependent on the robustness of their products. Product concept should be designed adaptable for initiated changes but resistant against unforeseen changes. But how can product structures be evaluated if they are robust? In this study, we present a methodology to evaluate the structural robustness by modeling and analyzing dependencies of product concepts in Multi-Domain-Matrices. We conducted four empirical case studies in industry to test and refine the methodology. The proposed methodology enables engineers to (1) to evaluate the structural robustness of product concepts in early phases, (2) to compare different product concepts in term of their structural robustness, or (3) to deduce improvements towards enhanced structural robustness systematically. The methodology can be applied in all phases of product development process. It supports sustainably the improvement of the product architecture, reduction of change costs, decision making in development processes, and systematic deduction of design guidance.

MODULAR OPTIMIZATION STRATEGY FOR LAYOUT PROBLEMS

Bénabès, Julien (1); Poirson, Emilie (1); Bennis, Fouad (1); Ravaut, Yannick (2)

1: IRCCyN, France; 2: Thales Communications, France

Layout design optimization has a significant impact in the design and use of many engineering products and systems. The search of an optimal layout configuration is a hard and critical task and designers need specific optimization strategies to achieve it. These strategies have to be generic to be adapted to a maximum of layout problems and a maximum of designer's requirements. These strategies have also to be effective in the search of optimal solutions without being too time consuming. Then, this paper proposes a modular optimization strategy based on the genetic algorithm. This strategy is adapted to multi-objective layout problems, when the designer has to make a final decision on optimal solutions. The optimization modules are used in order to make the search of feasible designs easier, by taking into account the specificities of layout problems. The different algorithms, which result from the modular optimization strategy, are tested and compared on a real-world application. This layout problem deals with the search of an optimal spatial arrangement of components inside a shelter.

MAINTENANCE ENGINEERING: CASE STUDY OF FITNESS FOR SERVICE ASSESSMENTS

Giacobbe, Francesco (1); Biancuzzo, Emanuele (2); Albino, Mirko (2); Geraci, Domenico (1)

1: INAIL, Italy; 2: Engineer, Italy

The current needs of the industrial market, such as the increasing production capacity, the conservation of the plant property, the reduction of the probability of plant shutdown, strongly lead to the discipline of Maintenance Engineering. As part of the pressure equipment, such as pressure vessels, piping, and tanks, the maintenance processes must be managed with a risk management logic. Through, Fitness For Service (FFS) method, pressure equipment presenting a structural degradation can be maintained in operation, with close monitoring. This study illustrates the application of the design code for FFS according to API RP 579 and BS 7910 in the case of a longitudinal defect (crack-like flaw) on a pipe in pressure conditions. The comparison is carried out using both codes in order to assess the stability of the defect. The calculation shows that the defect is stable, if the pipe is stressed with a steady load equal to the maximum admissible load in operation. The most conservative result has been obtained from BS 7910.



REQUIREMENTS FOR PRODUCT DEVELOPMENT SELF-ASSESSMENT TOOLS

**Knoblinger, Christoph (1); Oehmen, Josef (2); Rebentisch, Eric (2); Seering, Warren (2); Helten, Katharina (1)**

1: Technical University of Munich; 2: Massachusetts Institute of Technology

The successful execution of complex PD projects still poses major challenges for companies. One approach companies can use to improve their performance is self-assessment tools to optimize their organization and processes. This paper investigates the requirements regarding self-assessment tools for PD organizations. It summarizes the current literature on PD-related self-assessment tools and derives tool requirements from an industry focus group (US aerospace and defense industry) as well as from interviews at a major American defense contractor. The resulting requirements are: 1. Focus on proven PD best practices; 2. Formalized implementation process; 3. Tool customization guidelines; and 4. Integration with other process improvement approaches. A gap analysis comparing these requirements to the previously identified tools is performed. The paper concludes with the outline of an example PD self-assessment tool that addresses these requirements.

MANAGEMENT OF PRODUCT DEVELOPMENT PROJECTS THROUGH INTEGRATED MODELING OF PRODUCT AND PROCESS INFORMATION

**Oizumi, Kazuya (1); Kitajima, Kei (1); Yosie, Naoto (2); Koga, Tsuyoshi (1); Aoyama, Kazuhiro (1)**

1: The University of Tokyo, Japan; 2: DeNA

As complexity of products, specifically mechatronics, increased, management of development project becomes difficult. For better management of product development projects, this paper proposes integrated model of product and process information. Most information on a proposed model is described as Multi Domain Matrix (MDM), which is composed of Domain Mapping Matrix (DMM) and Design Structure Matrix (DSM). Further, to conquer a difficulty acquiring information as a model, this paper proposes methodologies for model based assistance for refinement of a model. To continuously refine a model, the methodologies suggest multiple cyclic processes. Then, computational methods to utilize acquired model is discussed. The proposed methods employ technics on DSM and DMM to deliberate possible candidates of development process, incorporating manageability of design process and resource allocation. As a result, it provides planners with arena to discuss tradeoff between development span and difficulty managing process. Finally, an example on solar boat development project shows plausibility of the proposed methods.

PROTOTYPING IN ORGANIZATIONAL PROCESS ENGINEERING

**Macri, Diego Maria; Vignoli, Matteo; Bertolotti, Fabiola**

U. of Modena and Reggio Emilia, Italy

Organizations are increasingly developing new forms of integration. With the support of Design, it is now possible to attain new forms of competitive advantage through organizational changes not feasible in the past. To enable these changes we design organizational processes, since they are considered a convenient level of analysis. This paper aims to suggest which are the appropriate techniques to prototype the different components of a process. We propose the use of Discrete Event Simulation for operational processes, of System Dynamics for behavioral processes and of Agent Based Modeling for change processes. We also aim to compare advantages and disadvantages of the different techniques. We argue that, in complex situations, several techniques should be simultaneously employed.

IDENTIFICATION OF SUITABLE PILOT PROJECTS IN THE FIELD OF LEAN DEVELOPMENT

**Helten, Katharina; Eben, Katharina; Lindemann, Udo**

TU München, Germany

The long term implementation of philosophies such as lean development requires special conditions and measures. Process improvements and positive effects of changes are difficult to prove. Pilot projects help to involve employees already in early stages. Through such projects, the development team is involved in all necessary phases such as process and waste analysis as well as the search for improving measures and their execution. The change is enforced through a “selfhelp approach” that is essential in SMEs that cannot afford staff functions. Therefore, the presented research project accompanies three companies during their lean development implementation to search for methods and measures that describe a successful pilot project. The authors support the companies through their knowledge in the field of lean development, the moderation of workshops and discussions and an ongoing evaluation. This paper presents a framework for the design of pilot projects based on the aspects company context, waste analysis and measure design. Furthermore, it gives an overview of the most influencing factors for the design of a pilot project and first findings from the project.

CONSIDERATIONS ON DESIGN MANAGEMENT OF FURNITURE MANUFACTURING COMPANIES IN SOUTHERN BRAZIL

**Bernardes, Mauricio Moreira e Silva; Galafassi, Ana**

FEDERAL UNIVERSITY OF RIO GRANDE DO SUL, Brazil

Managing design projects means to plan the new product development management and must involve knowledge on management, as well as of the design activities, to enable companies to become more competitive in the market in which they are active. With a focus on the industrial sector, this study has the goal to analyze the design management in the furniture manufacturing industry in the Taquari Valley, in the South of Brazil, a productive segment that has a relevant prominence in the Brazilian transformation industry. Nevertheless, the companies in this segment lack studies to help them in design management. This study was based on the proposition by Borja de Mozota, according to whom, design management is inserted in the three organizational levels: operational, tactical and strategic. The result of this study has shown that, even without a systematization and knowledge of the concepts, the researched manufacturers approach the question of design in their organizational levels.

MANAGING RESOURCE SCARCITY IN SMALL ENTERPRISES’ DESIGN PROCESSES

**Löfqvist, Lars Gunnar**

University of Gävle, Sweden

Small enterprises have scarce resources, which is the main factor hindering their innovation and design of new products. Despite this resource scarcity, some small enterprises do innovate and design new products. The research question is: how do small enterprises manage resource scarcity in their design processes? A multiple case study of three different small enterprises was used to answer the research question. The enterprises implement several approaches to use existing resources more efficiently or increase existing resources, such as reducing formality and including customers and users in the design processes, intertwining design processes, working concurrently on design and operational processes, adopting lead-user inventions, and only starting design processes when a current customer asks for or needs the potential new product. The efficiency of these approaches is found to be explained by common small enterprise characteristics. One conclusion from this study is that resource scarcity can be managed and small enterprises’ specific characteristics can facilitate innovation and design if these are recognized and used as strengths.

HOW PRODUCT REPRESENTATION TYPES ARE PERCEIVED AT THE CLIENT’S END TO FACILITATE COMMUNICATION AND DECISION MAKING

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The ability to communicate effectively, honestly and convincingly to design clients, according to the required level of understanding, is important to facilitate decision making in the designing process in a cost responsible manner. This article shows that the Design clients’ assessment of representation type according to level of detailing and completeness of communicated information reversably complements the level of allowance for design changes. “Presentation Drawings” communicate a high level of completeness, which is almost equal to “High Quality Presentations in CAD” and “Quality Design Models. As expected, iteration with the tactile volume creates a “near completion” assumption among design clients. A dualistic attitude can be observed among clients, when dealing with CAD models. Due to the incompleteness, but also viewing capabilities of initial CAD-models, clients were averagely neutral in their opinions concerning the level of design information provided by it. However, the representation quality of “Detailed Design Models” are being perceived similar to “Presentation Drawings”, because of their high level of detailing, realism and “frozen” mode of presentation.

ASSESSING THE CONDITIONS FOR DISSEMINATION OF END-USER AND PURCHASER KNOWLEDGE IN A MEDTECH CONTEXT

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A challenge for many medical technology companies is to satisfy the often differing needs and requirements of the purchaser of new medical technology and the end-user. This implies that medical technology companies have to consider knowledge from both stakeholders when developing new products in order to maintain an innovative edge. In this article we apply social network analysis to investigate, describe and compare the different patterns of social interaction that facilitate dissemination of end-user and purchaser knowledge in a business unit within a large medical technology company. The results indicate significant differences, both in structure and content, between the social interaction that facilitates the dissemination of end-user knowledge and that which facilitates dissemination of purchaser knowledge, respectively. Based on these findings, we argue that many medical technology companies may, by adapting their approach to the way they handle different types of customer knowledge, have untapped potential in increasing both their innovation performance and their competitive advantage. We conclude with suggested directions for future research on this topic.

DESIGNERS' THINKING AND ACTING IN MEETINGS WITH CLIENTS

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The present research attempts to contribute to the understanding of how designers’ thinking and acting enhance the value of the design process and deliver value to design results. The present study reports findings based on the analysis of video recorded meetings from a case study in a graphic design consultancy. This work is part of an empirical research study that aims to identify designers’ practices of value delivery across design disciplines. Previous findings derived from this research devise priority values for decision-making in design across disciplines. The present study reports findings on how these priority values are generated by designers’ patterns of thinking and acting throughout three team meetings working on the design of an exhibition. Evidence is given to the commonalities and differences between the design team and client’s team characteristics of thinking and acting in delivering value to design meetings and the creation of a combined model of such behavior. These results are intended for further study of its relevance in other design disciplines apart from the field of graphic design.

N-GRAM ANALYSIS IN THE ENGINEERING DOMAIN

Leary, Martin (1); Pearson, Geoff (1); Mazur, Maciej (1); Burvill, Colin (2); Subic, Aleksandar (1)

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New technologies have enabled the digitization and linguistic analysis of a vast number of books published throughout history. This technology has enabled a step-change in the opportunities to understand the interests of the authors and by doing so provide insight into the aspirations of society throughout published human history. Such analysis provides an unprecedented opportunity, however there are numerous analysis pitfalls due to fundamental technology limitations and misunderstanding of the analysis outcomes. This work defines the technologies which have enabled this opportunity and, in doing so, identifies potential risks of erroneous outcomes. A broad scope analysis of the engineering design domain is presented for the first time.

VISUALISING ERGONOMICS DATA FOR DESIGN

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1: Tongji University, Peoples Republic of China and Brunel University, UK; 2: Brunel University, UK

Existing ergonomics data are not effectively used by designers; this is mainly because the data are not presented in a designer-friendly format. In order to help designers make better use of ergonomics data, we explored the potential of representing existing ergonomics data in a more dynamic and visual way, and making them look more relevant to design. The Cambridge Engineering Selector (CES) was adopted to turn static ergonomics data into manipulative and comparative data sets. Contextual information in a visual format was added; clearer illustrations and scenarios relevant to design were developed; design case studies were compiled and linked to the relevant ergonomics data sets – the process resulted in a new design support tool: the ErgoCES. The tool was consequently brought to both design students and professionals for evaluation. The results suggested that the ErgoCES had helped making ergonomics data more accessible to designers, and many new features (e.g. scenarios and case studies) were highly valued by the designers. Among the participants, 100% of the design students and 79% of the professionals indicated that they would use the tool when it becomes widely available.

IT-BASED CONFIGURATION AND DIMENSIONING OF CUSTOMER SPECIFIC PRODUCTS – TOWARDS A FRAMEWORK FOR IMPLEMENTING KNOWLEDGE BASED DESIGN ASSISTANT SYSTEMS

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Individual product solutions require practicable concepts and IT support for fast product configuration and design. Knowledge of possible design options and basic conditions is of great significance in the conception of this type of support. The goal is an integrated conception and implementation of knowledge based IT applications for engineering design. Despite existing methodological support from software vendors, numerous questions still arise during requirements formulation, system evaluation, system integration into existing business IT environments, the creation of knowledge bases, the implementation of pilot process tasks, or definition of rollout and operation strategies. Illustrated by a case study, this paper presents the first results of a research project that deals with the systematic examination of the aforementioned issues with the aim to develop a framework for the holistic concept and the practical implementation of knowledge-based assistant systems. The main components of the presented approach are a practical method, an assistant for the acquisition and formalization of configuration and engineering knowledge as well as a system-neutral, federated knowledge base.



REQUIREMENTS OF A CARBON FOOTPRINTING TOOL FOR DESIGNERS

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This paper present the outcomes so far of a project to develop ‘co2ncept’, a carbon footprinting tool for product design concepts. It is clear that in order to be successful and useful to designers the tool must meet certain critical criteria. These criteria, including level of detail, language, assessment, information, visualisation, education, strategy, detail, user experience and interface are discussed. The project has already faced a number of challenges, including assumptions and boundaries, making carbon meaningful and sharing data. These are discussed. The paper concludes that the resulting carbon footprinting tool will need to assess the carbon footprint of a concept in a quantitatively accurate manner, allowing key aspects to be identified, hot-spots to be explored and provide strategic recommendations for improvement. It will serve as a quick assessment tool, but also as a communication and educational channel for environmental sustainability. It will help designers to identify opportunities while also creating awareness of the environmental impact of their decisions.

THE CONCEPT OF ECOLOGICAL LEVERS - A PRAGMATIC APPROACH FOR THE ELICITATION OF ECOLOGICAL REQUIREMENTS

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This paper uses the concept of product properties to analyze three different dimensions a product development has to cope with: technical, cost and ecological requirements. Objective is to highlight the problems when managing ecological product properties as well as to provide the basis for the elaboration of a pragmatic approach for eco-design practice. Pragmatic means securing the feasibility as to day-to-day work of product developers. The paper focuses on the early phases of a product development which constitute the most important ones in terms of task clarification. The full integration of ecological aspects in these phases is therefore promising and needs more methodical support. In this context, the concept of ecological levers is presented: Based on the ecological weak points of a product, the relation to design areas causing these weak points is displayed by means of so called effect chains. Having identified the design measures that can lead to a better ecological performance, their significance and feasibility is analyzed by a cost-benefit-analysis. By doing so, only the expedient measures are identified and formulated as requirements: these are the ecological levers.

INVESTIGATING THE REQUIREMENTS NEEDED TO MAKE APPROPRIATE END OF LIFE DECISIONS

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The purpose of this paper is to present the key findings on End of Life (EoL) decision making during product design, followed by a summation of the further research needed within the field. The methodology includes literature review of current publications, focus group discussions and telephone interview of designers. The main findings conclude that ecodesign and Life Cycle Analysis approaches are not suited to determining the EOL route for a product during the design process. Furthermore, EOL determination models have conflicting views as to when in the design process EoL decisions should be made, who should make the decisions and how the decisions are determined. The originality of this work is that it (i) studies the process of EoL decision-making from a designer’s perspective, and (ii) takes a holistic decision-making approach.

MODELLING TIME-VARYING VALUE OF AN END-OF-LIFE PRODUCT FOR DESIGN FOR RECOVERY

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Estimating residual value of an end-of-life product is an essential preliminary to design for recovery. This paper presents a quantitative model for estimating time-varying value of an end-of-life product. The model estimates the expected economic value of a product by considering two major depreciation factors, physical deterioration and technological obsolescence. The developed model is illustrated with an example of desktop computer and potential applications to design for recovery are presented. The model can contribute to enhancing the residual value of a product and/or improving the way of retrieving the residual value. It can also assist the recovery system design, such as product take-back planning and recovery strategy planning.

METHODOLOGY FOR CHOOSING LIFE CYCLE IMPACT ASSESSMENT SECTOR-SPECIFIC INDICATORS

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ICD - CREIDD - Université de technologie de Troyes (UTT), France

There is a wide range of indicators available for use in Life Cycle Impact Assessment (LCIA). For designers with limited experience of Life Cycle Assessment, it is difficult to decide which is the most likely to lead to a more environmentally friendly product. In industry, and in SMEs in particular, designers lacking the expertise needed to use LCA in an eco-design approach are liable to pay insufficient attention to indicator selection and may use inappropriate indicators that result in design faults. The lack of sector-specific methodological guidelines to assist them is another similar cause of problems.

This article describes the methodology of choice for selecting the most appropriate impact categories and characterisation models for a LCIA in order to facilitate the choice of eco-design solutions.

The two main stages of the methodology are described and explained.

This procedure can be used directly by individuals carrying out an LCA or by developers of specialised LCA tools that choose indicators for the user.

This methodology will make the LCA technique more accessible and better suited to designers' needs and so help encourage wider acceptance of the eco-design approach.

AN ENGINEERING-BASED ENVIRONMENTAL MANAGEMENT SYSTEM DESIGN

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1: The University of Melbourne, Australia; 2: RMIT University, Australia

Environmental imperatives necessitate formal Environmental Management Systems (EMS) to understand and manage the environmental consequences of commercial activities. A diverse range of EMS have been proposed, however these present limitations in accommodating changes in environmental performance, and do not incorporate fundamental process analysis to assess how the actual performance varies from what is theoretically achievable. A novel engineering-based risk evaluation framework has been developed that applies fuzzy logic and fundamental process analysis to overcome the identified issues.

TOWARD PROACTIVE ECO-DESIGN BASED ON ENGINEER AND ECO-DESIGNER'S SOFTWARE INTERFACE MODELING

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Integrating environmental concerns as well as other constraints (cost, quality, etc.) in the design process, requires to organize the process as a system. Specific software for each design expertise are created to embrace new demands and are supporting the design activity in such complexity that the interoperability between software is crucial.

The approach presented in this paper proposes a specific organization of the design process composed of \_local\_ and \_global\_ activities. The article focuses on the importance of modeling the data Inputs and Outputs exchanged between activities. It points out the necessity to defines rules of transformation that are needed to link models together. The system modeled allows an infinite number of interactions, and notably the integration of environmental concerns. This paper illustrates the method by studying a part of the design process of a simple product in a DTE approach. This case study involves software of material choice, CAD, LCA and focuses on transformation rules needed to give interoperable models. The results of the case study finally bring designers to adopt a new design of the product, which reduces initial environmental impacts.

PROCESS OPTIMIZATION BY DSM-BASED MODELLING OF INPUTS AND OUTPUTS

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Robustness is a major challenge for designing engineering processes. And processes are often modeled with Event-driven Process Chains (EPCs). However, the EPCs do not contain sufficient information for analysis and optimization of process robustness. We hypothesize that the quantity of interfaces, i.e. information exchange between tools or organizational units, is an indication for process robustness: The less interfaces occur in a process the more robust it is. And the purposeful interface alignment also improves its robustness. We developed a method for analysis and optimized realignment of process interfaces. We augment EPCs with input-output relations between activities. Then we transfer the process description into a Dependency Structure Matrix and apply a multi-criteria clustering for identifying activity groups, which can be executed without interfaces. The interfaces get assembled between the activity groups, i.e. we define stages for information handover between tools and organizational units. We applied the approach on processes of a mid-sized company and could reliably identify starting points for improving product robustness as well as new layouts of activity groups.

COMPARISONS OF DESIGN METHODOLOGIES AND PROCESS MODELS ACROSS DOMAINS: A LITERATURE REVIEW

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Challenges resulting from an changing environment affect all design processes, irrespective of whether the product designed is a machine, software, a building, services, etc.. These challenges require collaboration between domains, but current design processes of large systems, such as aircraft, essentially show separate development strands for each discipline. Research into methods to support these concepts is ongoing, but the original design methodologies have not been adapted accordingly. Based on a literature study this paper consolidates findings from different comparisons of design methodologies and process models across domains. A consensus can be found in most of the consulted studies that at least on an abstract level design process models have a generic core of common stages and activities. On a detailed level the picture is different. The extent to which design approaches appear similar across domains depends on the perspective of the analysis. The literature study provides an overview of important shortcomings of existing design methodologies which may serve as starting points for further research and development of design methodologies.

NEUTRAL DESCRIPTION AND EXCHANGE OF DESIGN COMPUTATIONAL WORKFLOWS

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1: Cranfield University; 2: Engineous Software GmbH

Proposed in this paper is a neutral representation of design computational workflows which allows their exchange and sharing between different project partners and across design stages. This is achieved by the de-coupling of configuration and execution logic. Thus, the same underlying workflow can be executed with different (fidelity) models and different software tools as long as the inputs and outputs of the constituent process are kept the same. To this purpose, an object model is proposed to define different simulation objects, their scope, and hierarchy in the simulation process. An XML based computer readable representation of workflows based on the proposed object model, is also suggested. The application of the proposed representation is demonstrated via a case study involving the exchange of workflows between two design partners. The case study also demonstrates how the same workflow can be executed using different execution tools and involving different fidelity models.

WHAT ARE THE CHARACTERISTICS OF ENGINEERING DESIGN PROCESSES?

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This paper studies the characteristic properties of Engineering Design (ED) processes from a process modeling perspective. In a first step, we extracted nine characteristics of engineering design processes from the literature and in a second step validated the findings using results from our survey among academic and industrial ED process modeling experts. In a third step, we added a further nine characteristics from personal experiences in the Language Engineering Domain to capture the pragmatic perspective. We arrive at a comprehensive set of 18 characteristics grouped into six challenges for process modeling in the engineering design domain. The challenges process modelers need to address when using and developing process modeling approaches and tools are: Development, Collaboration, Products & Services, Formality, Pragmatics, and Flexibility. We then compare the importance of elicited and suggested challenges and characteristics within engineering design with software engineering and business process modeling and discuss similarities and differences.

DECISION PROCESSES IN ENGINEERING DESIGN: A NETWORK PERSPECTIVE OF STAKEHOLDER AND TASK INTERACTION

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In recent years, there has been significant attention given to developing decision support methods and tools for engineering design. While advances in the formal, mathematical modeling and statistical mechanics based models have been impressive, this has not been the case for research attempting to reach beyond normative models to examine the cognitive and social factors that influence decision-making. In general advances have provided for either a top-down or bottom-up approach to decision-making; ignoring the requirements for both participant and task connectedness and dependencies. This paper describes an integrated modeling framework that uses a multi-network perspective of decision-making. The utility and extensibility of this framework are considered in discussion by way of examples from construction engineering design.

EXPLORING A DECISION MAKING FORUM IN EARLY PRODUCT DEVELOPMENT

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Decision making in early phases of product development is of great importance due to the large impact they have on the subsequent project, whilst in the same being heavily characterized by uncertainty. This paper explores decision making in early phases of product development, and reports empirical findings from a case study conducted in an automotive firm. The case study investigated a project meeting officially responsible for deciding the technical content of the product. For example it was found that defining working assumptions and asking questions were used as means to reduce uncertainty in the decision-making process, where three genres of questions were identified: elucidating, self enlightening and argumentative. Further, a number of challenges in managing the decision-making process were identified, specifically for such agenda-based meetings as in the case study which was found to rely on instant interactions between the participants. Project management e.g. instantly had to judge to widen or limit the problem discussed, or whether to continue probing a problem or stop the discussion in order to save the total meeting agenda.

A DECISION SUPPORT SYSTEM FOR THE CONCEPT DEVELOPMENT OF RIM PARTS

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The aim of this paper is to present a research project currently underway which seeks to identify and organize the knowledge required in the development process of Reaction Injection Moulding parts at the early product development stage, specifically the material selection, mould design and the process planning for mould making and moulding operation. The purpose of the research is to verify if an Expert System, a computer program that uses knowledge and inference procedures to model the RIM development process, provides the necessary insight into metrics such as development lead time and manufacturing costs to deal with the decision makings required at that stage. As this is a work-in progress, the paper will focus on the first three tasks carried out: 1) Structure the downstream processes and procedures of developing product design concepts for RIM parts; 2) Define the dimensions of knowledge required in the concurrent concept development of RIM parts; and 3) Present the theoretical implementation framework, the methodologies and procedures of an ES which we believe will help deal with concurrent concept development decision makings at the early design stage of RIM parts.

DECISION SUPPORT FOR IMPROVING THE DESIGN OF HYDRAULIC SYSTEMS BY LEADING FEEDBACK INTO PRODUCT DEVELOPMENT

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Hydraulic systems are used in great numbers and serve a variety of purposes. Still, however, the operating efficiency of hydraulic systems is not as high as it could be. New ways of monitoring the product use provide opportunities to maintenance. Through industrial product service systems the acquired product use information can be lead back into product development where it can be used to improve the development and quality of follower products. This paper presents a concept for leading feedback into product development and the state of implementation of a feedback assistant for decision support using statistical analysis methods and Bayesian Networks as a diagnosis and simulation method. The methods used have been validated on a centrifugal pump as an often used model hydraulic system.

Meeting the Energy Challenge: New Standards for Industrial Motor Efficiency



Mads Sckerl

Market Segment Director  
Grundfos Management A/S

Abstract

With an annual production of approximately 16 million pumps, production in 12 countries and a commercial representation in 52 countries, Grundfos takes its environmental responsibilities seriously.

Grundfos takes a life cycle approach to product development, which corresponds to the company’s “Total Cost of Ownership” (TCO) philosophy. This is important for Grundfos, as important pump improvements address the energy performance and service cost in the product’s operation period. These improvements include energy savings and increased overall pump efficiency. TCO can, therefore, be used to reveal the pump’s environmental profile.

Grundfos has lobbied actively to tighten the requirements for electric motors in the European Energy Using Product Directive, leading to energy savings equal to 5% of all electricity in EU. Mads Sckerl will present Grundfos’ motivation for this approach, and the results from the intensive work in this area.

Biography

Through his career, Mads Sckerl has worked in a large span of roles and businesses. These include operational as well as strategic-oriented management roles and smaller high-tech growth companies, as well as large mature companies. Mads has international industry experience from fibre-optics for telecommunications and from the pumps industry.

Central for his career has been business development in a broad context. His first managerial position was within a start-up company in the NKT Group. Later as Managing Director for Ignis Photonyx A/S a smaller international high-tech business.

Hereafter, Mads changed industry by joining Grundfos, the worlds leading pump manufacturer. First, holding the position of Business Development Director with responsibility for the group’s Controls and Motors products. In 2008, Mads became Segment Director for Water Utility. In this position, he defined the main objectives and the strategic direction for the group within the global water supply and waste-water business segment.

Designing Complex Systems for the 21st Century



Wei Chen

Wilson-Cook Professor in Engineering Design  
Northwestern University

Abstract

The design of complex “engineered” systems in the 21st century poses a set of common challenges, to name a few, the complexity and computational cost of system analysis, the heterogeneity of information at different levels of abstraction, the various sources of uncertainties, the multidisciplinary organization with conflicting goals, and the difficulty in understanding the socio-technical interfaces. Classical systems engineering approaches which focus on processes for cascading engineering requirements from higher to lower system levels is no longer suited to dealing with the global and socio-technical aspects of the 21st century complex systems. This presentation will first explore the research challenges and opportunities in designing complex “engineered” systems, and then focus on two specific topics in this area, i.e., (1) design of multiscale systems and (2) integrating heterogeneous consumer preference into enterprise-driven product design. Research in multiscale design presents the significant benefits of using computational design techniques for designing novel materials, new products, and new processes with exceptional system performance across diverse application domains such as material, energy, and medicine. Integrating consumer choice models into product design demonstrates the potential of combining analytical choice modeling with social networks for studying the social influence on new product adoption. It is concluded in this presentation that as systems continue to grow with increased complexity and more stringent requirements, many unanswered questions can be tackled using rigorous design methodologies.

Biography

Dr. Wei Chen is the Wilson-Cook Chair Professor in Engineering Design at Northwestern University. Affiliated with the Segal Design Institute as a Faculty Fellow, she is a Professor in the Department of Mechanical Engineering, with courtesy appointment in the Department of Industrial Engineering and Management. Directing the Integrated DESign Automation Laboratory (IDEAL- <http://ideal.mech.northwestern.edu/>), her current research involves issues such as simulation-based design under uncertainty, model validation, stochastic multiscale analysis and design, robust shape and topology optimization, multidisciplinary optimization, consumer choice modeling and enterprise-driven decision-based design. She is the co-founder and Director of the interdisciplinary doctoral cluster in Predictive Science and Engineering Design (PSED) at Northwestern, a program aiming for integrating scientific, physics-based modeling and simulation into design of innovative “engineered” systems.

Dr. Chen received her Ph.D. from the Georgia Institute of Technology in 1995. She is an elected member of the ASME Design Engineering Division Executive Committee and currently serving as the executive chair of the Technical Committees. She is also an elected Advisory Board member of the Design Society, an international design research community. She is an Associate Editor of the ASME Journal of Mechanical Design and serves as the review editor of Structural and Multidisciplinary Optimization.



SHARING EXPERIENCE IN DESIGN EDUCATION BASED ON RESEARCH AND INDUSTRIAL PRACTICE

**Hosnedl, Stanislav; Srp, Zbynek**  
*University of West Bohemia, Czech Republic*

We present and share our experience obtained through education in a degree-level course on system design engineering of technical products, in which we successfully integrate an engineering design research, education and industrial practice. We focus on and share the experience with the key instrument of this concept, which are the education design projects for industry solved by cross-disciplinary student teams. We have identified and present nine key factors that help our students and ourselves to achieve valuable and repeatably validated long-term results of these projects.

ADAPTING INDUSTRIAL DESIGN EDUCATION TO FUTURE CHALLENGES OF HIGHER EDUCATION

**Liem, Andre; Sigurjonsson, Johannes B.**  
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This paper discusses how Design Education should be adapted to the future challenges of higher education. Four (4) trends will be presented on how prospective design programs are to be developed. These are (1) Mass-Education and Rationalisation, (2) Links between Education and Research, (3) Globalisation and Internationalisation, (4) Intensification of Collaboration with Industry and Commercialisation of Research. In terms of manpower resources, the following academic configuration is proposed:

- Faculty inclined towards mentorship and scholarship, able to promote inquiry from a theoretical and process perspective.
- Faculty engaged in mentorship and service, capable of expanding their design programs beyond the “Physical home-based classroom”.
- Professional designers, who can contribute in skills development and design thinking based on experiences from practice.

On the receiving end, students should be trained to commute from generic to specialist and from abstract to concrete modes of working. Comprehensive studio projects should be implemented as platforms, where social and interdisciplinary learning can develop in line with selected design themes, processes and methods.

AN ETHICAL STANCE: ENGINEERING CURRICULA DESIGNED FOR SOCIAL RESPONSIBILITY

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Engineering must provide the global community with socially responsible, ethical and sustainable design solutions. The potential for engineering designers to contribute positively to the betterment of society, through product service systems that provide opportunities for sustainable development, enhance societal well-being and empower communities to be self determining, must be realised. This will require the engineering community to take leadership roles in product design and development and to engage with emerging economies to deliver appropriate designs and sustainable technologies.

Social responsibility and sustainability will need to be at the forefront of product design and development and more importantly, integrated throughout engineering education. As global designers, engineering graduates must be ethical and responsible, fully cognizant of the consequences of their professional activities, their potential for global societal contribution and their responsibilities to all stakeholders and communities. Opportunities exist for well considered curricula to drive new engineering paradigms and determine attitudinal change amongst the next engineering designers.

A PROPOSAL FOR AN ASSESSMENT FORM FOR ENGINEERING DESIGN THESES

**Watty, Robert (1); Kreimeyer, Matthias (2)**  
*1: BW Cooperative State University, Germany; 2: MAN Truck & Bus AG*

To evaluate a student’s work best possible, the assessment of theses written as part of the curriculum has to meet certain standards from both an academic and an industrial perspective to fully embrace the goals of engineering education.

Most universities usually use standard forms for the evaluation of theses. For the purpose of this research, available assessment forms within the Berliner Kreis, the German-speaking network of university institutions active in design education and research, were collected, compared and interpreted in order to find common evaluation criteria and to judge the current state of how theses in design education are evaluated.

This paper shortly describes the theoretical background to evaluation of engineering theses, it presents the results of a comprehensive study about current German and international evaluation procedures and criteria, and it concludes on future directions for the evaluation of theses in universities.

The result of the observation is a proposal of a comprehensive evaluation form for theses that could be adapted to special needs of evaluating institutions.

PLANNING INDUSTRIAL PHD PROJECTS IN PRACTICE: SPEAKING BOTH 'ACADEMIA' AND 'PRACTITIONESE'

**Kihlander, Ingrid; Nilsson, Susanne; Lund, Katarina; Ritzén, Sofia; Norell Bergendahl, Margareta**  
*KTH Royal Institute of Technology, Sweden*

This paper discuss the planning and organising of research conducted by Industrial PhD students, i.e. PhD students conducting research studies aiming for a PhD while employed in industrial companies. Industrial PhD projects within engineering design research in Sweden can be considered a phenomenon, i.e. existing but sparsely documented. This paper provides empirical illustrations by presenting three Industrial PhD projects conducted in three companies with product developing operations in Sweden. The specific research design of Industrial PhD projects provides benefits such as an effective bridging between academia and industry. Additionally, this type of research projects face challenges, such as having two-folded aims of the project: both academic and industrial goals. Based on experiences from these projects, implications for planning and organising of future Industrial PhD projects are discussed. Finally, we suggest that Industrial PhD projects are effective means, if used properly, for assimilation of research findings to industry, and for academia to understand the industrial practice.

MACHINE PART EXHIBITION AND FUNCTIONAL MOCK-UPS TO ENRICH DESIGN EDUCATION

**Beckmann, Gregor; Krause, Dieter**  
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Mechanical engineering design education has the objective to provide students with the required knowledge and skills to develop state of the art products. Besides theoretical teaching of fundamentals, practical hands-on experience supports this learning process. This constitution presents a new approach to integrate hands-on elements into design education curriculum under the constraints of large classroom sizes. Therefore, the need of improvements in design education is analysed and the concept of an interactive machine part exhibition is derived from pre-existing approaches. The exhibition is the corner stone of the concept and contains physical models of fundamental machine parts as well as sophisticated mechanical systems. These are used to create a link between lectures and the real objects. Moreover, functional mock-ups, specially prepared to teach students design, are used to improve an existing first year design and drawing exercise. The paper is closed with an outlook to the necessary evaluation of the concept that will be performed when the currently on going implementation into everyday teaching is completed.

THE DESIGNEXCHANGE: SUPPORTING THE DESIGN COMMUNITY OF PRACTICE

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The study of design – and more specifically, the quality of the process of design – has been shown to have high impact and leverage on the quality and success of engineered products. As design research does not fall into any one disciplinary body of knowledge, there is a need to consolidate and organize the many design research methods used, develop a community of practitioners to evaluate and categorize those methods and educate the next generation of design innovators in appropriate methods. In this paper, we introduce a preliminary design for \_The DesignExchange\_, an interactive web portal to meet these needs.

LEAN PRODUCT DEVELOPMENT: HYPE OR SUSTAINABLE NEW PARADIGM?

Catic, Amer (1); Vielhaber, Michael (2)

1: Chalmers Technical University, Sweden; 2: Saarland University, Germany

The idea of lean product development (LPD), with Toyota used as the main case in point of demonstrating its abilities, has gained attention among managerial levels of companies dealing with product development. Allegedly the main gains of LPD are a high rate of successful projects in terms of cost and quality along with shorter lead times as well as fewer overruns in time and budget. This paper investigates the lean product development concept in comparison with established models in the current product development paradigm in order to map out the main differences. It also compares LPD to the way product development is carried out in practice on the example of two large European automotive companies.

The results show that the main differences, among others, can be found first in the way knowledge is honored and managed, and second how and when decisions are made along the process. From the discussion of the results, conclusions are drawn for potential improvements to traditional product development models.

LEAN APPROACH TO INTEGRATE COLLABORATIVE PRODUCT DEVELOPMENT PROCESSES AND DIGITAL ENGINEERING SYSTEMS

Vosgien, Thomas (1); Jankovic, Marija (2); Eynard, Benoit (3); Nguyen Van, Thomas (1); Bocquet, Jean-Claude (2)

1: Snecma, SAFRAN Group, France; 2: Ecole Centrale Paris (ECP), France; 3: Université de Technologie de Compiègne (UTC), France

Lean philosophy has proven to have positive results concerning efficiency and reduction of overall process time. Product Development (PD) processes has an important role in the value definition and therefore in the past few years industrialist and researchers have shown a great interest in transferring the lean principles to PD processes; called Lean Product Development (LPD) or Lean engineering. In this paper we propose to address the literature overview of LPD and the difficulties in developing an adequate value system in the implementation process especially with the changes undergone in the development process. Moreover, we propose to expand the definition of the value and related metric system within research study currently ongoing in aircraft industry. Our proposition concerns developing digital tools capabilities while matching them with some design processes. Based on a lean approach, the goal is to demonstrate how this matching can be a value creation driver within the Collaborative Product Development (CPD) of an Integrated Power Plant System, i.e. design and integration of turbojet engine, nacelle, pylon and connected equipments.

DEVELOPMENT OF A FRAMEWORK FOR IMPROVING ENGINEERING PROCESSES

Pepe, Carla (1); Whitney, Daniel (2); Henriques, Elsa (3); Farndon, Rob (1); Moss, Michael (1)

1: Rolls-Royce, United Kingdom; 2: MIT - Massachusetts Institute of Technology; 3: IST - Instituto Superior Técnico

The complexity of designing products such as gas turbine components leads to enormous difficulties in understanding where the main design process inefficiencies are. It is extremely difficult to decide which improvements will have the most significant impact for a company or for a specific project. Another common issue found in the Aerospace industry is a consequence of basing a new gas turbine design on a previous concept and is that most of the time people don't question the overall design process. These issues, alongside a companies' matrix organization, create difficulties in managing and improving the design processes. In order to overcome the mentioned problems, a framework has been developed and used in Rolls-Royce. This framework aims to assess and improve in a systematic way, complex product development processes at component or system level. The framework involves the use of Value Stream Mapping (VSM) analysis to identify waste sources in the design process, the use of Design Structure Matrix (DSM) to manage design iterations and interfaces complexity and process simulation to deal with the stochastic behavior and estimate and assess the benefit of potential developments.

CREATING VALUE THROUGH LEAN PRODUCT DEVELOPMENT – APPLYING LEAN PRINCIPLES

Swan, Anders Håkan (1); Furuholm, Jörgen (2); Tingström, Johan (3)

1: Ivolver AB, Sweden; 2: Saab Aerosystems, SAAB AB; 3: Scania AB

This conceptual article describes how companies can create value through applying Lean principles in product development. It provides input to a generic framework of Lean Product Development as it defines an explanatory model for effective knowledge enhancement and execution of development projects. The model consists of a two by two matrix given by a division of, at one hand, product development in two value streams, the Product Value Stream and the Knowledge Value Stream, and at the other hand in two phases, the Concept phase and Implementation phase. With this as basis it is discussed how four essential Lean principles, Flow, Continuous Improvement, Standardization and Visualization, could be applied.

PRODUCT DEVELOPMENT PROCESSES IN SMALL AND MIDDLE-SIZED ENTERPRISES - IDENTIFICATION AND ELIMINATION OF INEFFICIENCY CAUSED BY PRODUCT VARIETY

Eben, Katharina G. M.; Helten, Katharina; Lindemann, Udo

Technische Universität München, Germany

Competitiveness of small and middle-sized enterprises (SME) represents recognizing customer needs and being able to efficiently react to it. As SMEs face a limitation of their resources, it is crucial to monitor the strategy of product variety management and the interplay of project work and day-to-day business. This paper aims to achieve the former by identifying and eliminating inefficiencies in product development processes. Thus, a procedure is introduced to reduce development effort by successfully handling the necessary product variety. Further goals are to avoid sources of inefficiency – to improve the interplay between development process and everyday work – and to gain consciousness about how the processes are lived within the enterprise and how product variety impacts on the day-to-day-business.

RE-CONCEPTUALISING VALUE IN ENGINEERING DESIGN PROCESS: THE VALUE CYCLE MAP

Siyam, Ghadir; Wynn, David; Clarkson, John

University of Cambridge, United Kingdom

Introducing "Cheaper, Faster, Better" product in today's highly competitive market is a challenging target. Therefore, for organizations to improve their performance, they need to adopt methods, such as process modeling, risk mitigation, and value lean principles. Recently, several industries and researchers focused efforts in transferring value concept to other phases of the Product Life Cycle (PLC), such as Product Development (PD), after its evident success in manufacturing.

In PD, value, which is the main objective of lean theory, has been of particular interest as an improvement concept that can enhance process flow logistics and support decision-making. This paper presents an on going study of the current understanding of value in PD (VPD) with a focus on value dimension and implementation benefit. The purpose of this study is to consider the current value state of knowledge in proposing a definition of value and a framework for value delivery. The framework- named Value Cycle Map (VCM)- intends to facilitate understanding value and its delivery mechanism in the context of PLC. VCM can be used as a foundation for future research in value modeling and measurement in PD.

SELECTION OF DESIGN CONCEPTS USING VIRTUAL PROTOTYPING IN THE EARLY DESIGN PHASES

Buda, Andrea; Seppälä, Mikko; Coatanéa, Eric

Aalto University School of Engineering, Finland

One of the challenges in the early phases of a product development process is the need to make fundamental decisions regarding the selection of design concepts. The use of virtual prototyping right from the early stages provides a means to rapidly develop design variants that can be analyzed in order to support these decisions. This article presents a systematic method for the evaluation of design concepts based on the performance assessment of dynamic virtual prototypes. The implementation alternatives for different functions are summarized in a Zwicky matrix. To manage the testing process and to analyze the results we use the Taguchi design of experiments method. The results are finally used to select the best design concept out of the Zwicky matrix. The details of the proposed method are presented and applied for the development of a vacuum cleaner robot. In order to describe the dynamic behavior of each concept immersed in its environment, our approach leverage on a 3D physics simulator connected in closed loop with a finite state machine control logic.

USING VIRTUAL REALITY IN DESIGNING THE ASSEMBLY PROCESS OF A CAR

Becker, Ilse (1); Toivonen, Ville (1); Leino, Simo-Pekka (2)

1: Tampere University of Technology; 2: VTT Technical Research Centre of Finland

This paper presents a study of a company that is testing virtual reality (VR) tools in designing the assembly process of a new car model. This is the first time in the company's 40-year history that virtual reality is used in the designing process. The company designed its production processes simultaneously with the product development which was done by a newly founded company located on another continent. A benchmark research was made in the case company to find out, which virtual tool features are needed when designing an assembly process. Collaboration usage of the virtual reality tool was tested with the product development (PD) over internet. A review of the existing literature showed that the focus of the research in VR has been mainly in product development or in single subassemblies. Different kinds of systems were found with various features. Regarding the assembly, some system features were essential for virtual prototyping. No literature about similar cases was found where the target was to design the whole assembly process sequence of a brand new vehicle designed by a brand new company collaborating for the first time in a tight schedule.

REALIZING A TRULY 3D PRODUCT VISUALIZATION ENVIRONMENT – A CASE FOR USING HOLOGRAPHIC DISPLAYS

Opiyo, Eliab Zephania

Delft University of Technology, Netherlands, The

Recent advancements in the areas of visualization have led to realization of a large variety of three-dimensional (3D) visualization technologies. As adopting a new technology can sometimes result into unexpected adverse consequences, a structured approach to visualization technology selection and planned utilization and maintenance is naturally indispensable. Some general-purpose guidelines and methods for selection of technologies are available and could probably be adapted and used, but none of them square precisely with the challenge of selecting visualization technology for product visualization. This paper describes the systematic method we put together and followed, the actions we took, and factors we considered; which lead to categorization of holographic display as a viable truly 3D product visualization technology. Such a systematic approach, factors and actions, when appropriately considered, could help industrial organizations aspiring to invest in new visualization technologies to make measured selection, and could also guide them towards better utilization and maintenance, which would ultimately justify investing in the selected technology.

THE BENFITS AND PITFALLS OF DIGITAL DESIGN TOOLS

Marion, Tucker J (1); Fixson, Sebastian (2)

1: Northeastern University, United States of America; 2: Babson College, United States of America

Digital design has become pervasive to all aspects of the development process. The potential benefits of digital design include rapid iterations, the development of quick prototypes, and the ability of the team to virtually model entire systems without expensive physical prototypes. Digital design has now migrated to the beginning of the development process during ideation and conceptual design. Through empirical and case-base research we report on the challenges and opportunities of employing digital design early. We find that digital design can lead to back-loading, a condition in which digital design can short-cut valuable conceptual iteration. We also find that the integration of digital design into the development process needs to maintain distinct phases and firms must maintain a balance of creative iteration with process discipline. Finally, we find that there is a direct correlation between firm R&D efficiency and their strategy for IT infrastructure, process discipline, and use of digital design support tools.

AUTONOMOUS VISUALIZATION AGENTS TO ENHANCE THE ANALYSIS OF VIRTUAL PROTOTYPES

Radkowski, Rafael; Gausemeier, Jürgen

Heinz Nixdorf Institute, Germany

A virtual prototype specifies the shape and the behavior of a product under development. However, it is a computer-internal representation of this product and suitable visualization techniques are necessary to understand the structure and behavior of it. Today visualization techniques are selected manually by the developers; that is time consuming and error-prone. In this paper, we introduce the concept of autonomous visualization agents: software agents that select autonomously a proper visualization for a certain task. To realize such agents an agent model to represent the knowledge of the agent, as well as a reasoning mechanism are necessary; both are introduced. Experiments have been carried out to test the correctness and the usability of the models and the reasoning mechanism. The experiments show that the models and the reasoning mechanism facilitate the autonomous selection of visualizations by software agents.

INTERACTIVITY IN EARLY-STAGE DESIGN BY REAL-TIME UPDATE OF STRESS INFORMATION FOR EVOLVING GEOMETRIES

Trevelyan, Jon (1); Scales, Derek (2)

1: Durham University, United Kingdom; 2: University of Western Australia, Australia

A methodology is introduced for the analysis of small problems of elasticity in which the stress solutions, displayed in conventional contour form, are updated in real time as the engineer deforms the geometry of the object under analysis. The underlying mathematical technique is the Boundary Element Method, and we show how the method can be adapted for continuous update of stress solutions as the geometry evolves. Two performance enhancement strategies are presented, and an illustrative example shows a typical usage of the software tools produced during this project.



CONTEXT-SPECIFIC EXPERIENCE SAMPLING FOR EXPERIENCE DESIGN RESEARCH

Kim, Yong Se; Hong, Yeon Koo; Kim, Jin Hui; Kim, Young Mi

Creative Design Institute, Sungkyunkwan University, Korea, South (Republic of)

Despite apparent benefits of Experience Sampling (ES) for experience design and research, it has been scarcely used in the field. Among the reasons for that are some methodological issues such as the way in which conventional ES gathers contextual experience information directly from the participants' description of the context and the lack of theoretical framework enabling researchers to systematically explore and extract meaningful experiences. To address these issues, the researchers have developed an adapted ES model, entitled 'Context-Specific Experience Sampling' which integrates a rigorous data collection and analysis processes. The model explains how to gather context-specific user experience information and then extract key experience attributes from the data pool through. This divergent-to-convergent approach is described 'experience pooling, sorting, and extracting' under the theme of experience processing. This paper explains in detail the structure and procedure of the model with examples obtained from a small scale office environment research.

PROPOSAL OF "EXPECTOLOGY" AS DESIGN METHODOLOGY

Murakami, Tamotsu; Nakagawa, Satoshi; Yanagisawa, Hideyoshi

University of Tokyo, Japan

In the present competitive environment, designers should challenge to create attractive products to give consumers not just satisfaction as expected but delight beyond expectation. For that purpose, the authors propose a concept of \_Expectology\_ as a framework to provide designers with a systematic methodology of designing products considering every possibility of consumers' positive (e.g., expectation, satisfaction, delight) and negative (e.g., anxiety, dissatisfaction, disappointment) emotional response. As a systematic approach to \_Expectology\_, first the authors enumerate and qualitatively classify relevant emotional states by a combination of two exclusive categories, prior-posterior and positive-neutral-negative, for an analysis in MECE (mutually exclusive and collectively exhaustive) manner. Then the authors enumerate all possible transitions from one emotional state to another as a matrix. This classification matrix provides designers with means of classifying both successful and unsuccessful design case studies and relevant design methods and techniques and compiling design databases (e.g., as web pages) of what they should or should not do for the future projects.

THE PSYCHOLOGICAL EXPERIENCE OF USER OBSERVATION

Gerber, Elizabeth

Northwestern University, United States of America

While scholars have studied what design practices accomplish, few have considered how people feel when enacting these practices and the implication of these feelings on design work. An eighteen-month ethnographic study of a high-tech firm examined the psychological experience of engaging in the practice of user observation. The study finds that user observation supports regular exploration. Regular observation supports curiosity, or the tendency to focus attention and seek answers to unanswered questions. Results suggest how design work practices can be designed to help employees manage in uncertain conditions.

MONITORING DESIGN THINKING THROUGH IN-SITU INTERVENTIONS

Lande, Micah; Sonalkar, Neeraj; Jung, Malte; Han, Christopher; Banerjee, Banny; Leifer, Larry

Stanford University, United States of America

Abstract - Building on existing knowledge of design and design thinking we apply several other fields of knowledge such as emotion coding, improvisation, ethnography, social psychology, and decision analysis into key metrics we call Design Thinking Metrics (DTM). We applied these metrics to analyze and assess videos of software design teams. We then conducted a workshop series with a professional software design team to use DTM as a perceptual tool to test a number of action-repertoires that could be used to improve Design Thinking practice. The result is multi-disciplinary perceptual monitoring of design thinking activity in professional software practice.

GLOBAL OPTIMIZATION OF ENVIRONMENTAL IMPACT BY A CONSTRAINT SATISFACTION APPROACH – APPLICATION TO SHIP-ECODESIGN

Larroude, Vincent; Yvars, Pierre-Alain; Millet, Dominique

Supméca - LISMMA, France

After demonstrating the feasibility of the inversion of a ship emission model with the CSP approach, we will now discuss about the optimization of emissions. In a first time, a single-objective approach with an aggregation function of the emissions will be used, then, it will be a multi-objective approach and the Pareto frontier will be computed. The objective of this paper is triple: first, to show that a full ship model, linking a propulsion model and an emission model, can be inverted. Then, to bring to light that a propulsion system can be sized by an approach minimizing the emissions and using an aggregate function. Finally, to demonstrate that, in this case, computing the Pareto frontier provides the same global optimum as the mono-objective approach.

EXTRACTION AND ANALYSIS METHODOLOGY FOR SUPPORTING COMPLEX SUSTAINABLE DESIGN

Liang, Helen (1); Birch, David (2)

1: University of Bath, United Kingdom; 2: Imperial College, London

The advent of computer-based tools to aid the design process has meant that larger set of design parameters can be taken into consideration. It also means that other factors, such as those associated with environmental issues can be considered, and increasingly there are legislative requirements to do so. This means increasing demands are placed on designers to create innovative, sustainable, high quality solutions to satisfy a large range of stakeholders. Design is an interdisciplinary practice that is inherently complex. Managing such complexities requires the support of specifically created tools and methodologies in order to handle the large number of available design parameters. This is particularly true of the built environment where such parameters include the number and mix of buildings, their energy consumption, the handling of waste, the management of water, and the transport needs. The paper discusses the use of a methodology that seeks to support the decision making process and design optimization for complex sustainable designs based upon automatically studying the relations between design parameters so that their interdependencies can be obtained and sensitivities established.

DESIGN FOR ADDITIVE MANUFACTURING TECHNOLOGIES: NEW APPLICATIONS OF 3D-PRINTING FOR RAPID PROTOTYPING AND RAPID TOOLING

Junk, Stefan; Tränkle, Marco

University of Applied Sciences Offenburg, Germany

The application of additive manufacturing technologies is becoming established in an increasing number of product development sectors. This allows a number of additive manufacturing technologies to be used quickly and inexpensively for prototypes and also small series. Furthermore, tools can also be manufactured with additive technologies due to the considerable increase in the range of materials which can be used in recent years. For all these applications it is particularly important to take into account also the special requirements for the design in addition to the quick and inexpensive manufacture of the prototypes and components when applying these new manufacturing technologies. Furthermore, the operating principle of these new technologies, with which the material is usually built up in layers, also offers numerous new design options which reach far beyond conventional design. The innovations of the design process, in particular, are worked out for the 3D printing technology and their benefits illustrated in this paper. Besides the technical boundary conditions, the economic advantages and disadvantages in comparison to conventional technologies are also described.

THE IMPACT OF SAFETY STANDARDS AND POLICIES ON OPTIMAL AUTOMOBILE DESIGN

Hoffenson, Steven; Papalambros, Panos Y.

University of Michigan, United States of America

Much of the recent decline in road traffic injuries and fatalities is attributed to regulations imposed by governments and crash test ratings produced by public and private institutions. These crash tests aim to provide a standardized method for crashworthiness comparisons between vehicles, and they do so using prescribed crash scenarios that purportedly represent real-world crashes. Because the results of these tests are made public and influence consumer demand, automakers commonly optimize their vehicle designs specifically to perform well in these crash scenarios. This study explores the impact of three particular specifications of the National Highway Traffic Safety Administration New Car Assessment Program frontal crash test on optimal automobile design, including the test speed, the injury severity, and the ratings system used to present the results. Optimal vehicle designs for the original crash test are compared with those of alternative test scenarios, and the impact of such designs is discussed. Findings show that scenarios representative of more frequently-occurring on-road crashes appear to produce safer vehicles, and a more precise ratings system is recommended.

INTEGRATED PRODUCT & PRODUCTION MODEL – ISSUES ON COMPLETENESS, CONSISTENCY AND COMPATIBILITY

Gedell, Stellan (1); Claesson, Anders (2); Johannesson, Hans (1)

1: Chalmers, Sweden; 2: Saab Automobile AB, Sweden

Product development of complex products and their corresponding production systems continue to provide challenges in industry as well as interesting and challenging research questions. Recent research in the area has provided an integrated product and production system modeling framework supporting cross-functional collaboration and concurrency. An industrial challenge of ensuring complete sets of parts for manufacturing of different product variants is examined. The work includes a framing of the concepts of completeness, consistency, and compatibility. Based on this framing a case study is conducted exploring the possibilities and implications involved in using the modeling framework to include supporting functionality.

A KNOWLEDGE-BASED MASTER MODELING APPROACH TO SYSTEM ANALYSIS AND DESIGN

Sandberg, Marcus (1); Tyapin, Ilya (1); Kokkolaras, Michael (2); Isaksson, Ola (3)

1: Luleå University of Technology, Sweden; 2: The University of Michigan, USA; 3: Volvo Aero Corporation, Sweden

The jet engine industry relies on product models for early design predictions of attributes such as structural behavior, mass and cost. When the required analysis models are not linked to the governing product model, effective coordination of design changes is a challenge, making design space exploration time-consuming. Master modeling (MM) approaches can help alleviate such analysis overhead; the MM concept has its origins in the computer-aided design (CAD) community, and mandates that manual changes in one model automatically propagate to assembly, computer-aided manufacturing (CAM) and computer-aided engineering (CAE) models within the CAD platform. Knowledge-based master models can also be used to communicate changes in the product definition to models that are external to the CAD platform. This paper presents details of the knowledge-based master modeling approach as applied to mechanical jet engine analysis and design, where different fidelity models and analysis tools are supported in the early design stages.

ECO TRACING - A SYSTEMS ENGINEERING METHOD FOR EFFICIENT TRACELINK MODELLING

Stark, Rainer (1,2); Figge, Asmus (1)

1: Technische Universität Berlin, Germany; 2: Fraunhofer Institute for Production Systems and Design Technology, Germany

Using expertise and combining functionalities from different domains has led to a significant increase of information engineers have to deal with. It is hardly possible to identify influenced components in activities like change requests. A model containing tracelinks between the elements of involved partial models as an essential part of PLM based Systems Engineering helps to overcome this deficit. The main obstacle for a broad introduction of traceability is the significant workload involved in creating tracelink models as every element combination has to be examined for dependencies. This calls for an approach to support developers in creating tracelink models more efficiently. The presented approach Eco Tracing allows developers to significantly Economize modelling effort. In order to do so, the method uses the hierarchical structure of many models and a top-down analyzing approach to exclude element combinations prior user examination. Furthermore Eco Tracing allows choosing the desired level of detail flexibly while modelling. Eco Tracing is a promising approach helping to establish traceability in product development by reducing modelling effort significantly.

SOCIAL SYSTEMS ENGINEERING – AN APPROACH FOR EFFICIENT SYSTEMS DEVELOPMENT

Naumann, Thomas; Tuttass, Ingo; Kallenborn, Oliver; Königs, Simon Frederick

Daimler AG, Germany

Our objective is to establish an understanding of product development as a sociotechnical system. This approach should help to explain today's phenomena in product development and represents the basis for the development of new methodical approaches that help to manage. Our vision is to enable real-time analysis of organisational efficiency for the self-organisation of social systems as well as to facilitate effective development of technical systems = Social System Engineering.

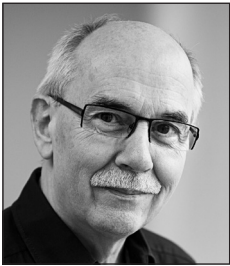
A schematic meta-model of sociotechnical systems displays the whole system, subsystems, structures and system functions. The system functions of social system and technical genesis are executed by interaction and communication. Based on this approach, complexity can now be identified in the technical and social subsystem. Furthermore, the meta-model is the base for the development of engineering services and tools. A detailed UML meta-model was derived from the schematic meta-model of sociotechnical systems with the objective to improve effective system modelling and efficient system development.

Reflections in the Context of the History of Design Research

In the past 50 years the number of researchers in the field has expanded enormously – as has the number of publications. During the same period design practice and its products have changed dramatically. Nowadays designers can seldom focus on individual 'products' but must address, for example, large complex product/service-systems (PSSs) that require the integration of many different advanced technologies over the whole life cycle of such systems. The processes by which these PSSs are designed and produced are also now far more complex and distributed, putting designers under ever increasing pressure.

We shall address the question: Are the results of Design Methodology research appropriate and are they delivering the expected results in design practice? In our attempt to answer this question we shall draw on our extensive experience of design research and design teaching, and on the recent book The Future of Design Methodology, edited by Professor Herbert Birkhofer. We shall also refer to a model that links the Results, Practices, Methods, and Sciences of designing.

Some initial conclusions: Design Methodology research often fails to support the tasks currently confronted by practising designers; many valuable research insights are not transferred into practice; the design research field is fragmented and there is a need for consolidation; however, the current design research community is beginning to demonstrate a greater awareness of the needs of designers and to apply greater rigour in its research.



Mogens Myrup Andreassen

MSc MechEng, PhD, Dr-Ing EH  
Professor Emeritus of Product Development (DTU)  
Honorary Fellow of Design Society



Ken Wallace

BSc, FREng  
Professor Emeritus of Engineering Design (Cambridge)  
Honorary Fellow of Design Society

Mogens Myrup Andreassen is Professor Emeritus of Product Development. He holds a PhD in Product Design and an MSc in Mechanical Engineering. His research interests are design methodology, 'Design for X' methodology, integrated product development, conceptualisation, and applications of the theory of technical systems.

As well as being an eminent academic, he was one of the founders of WDK which initiated the internationally renowned series of ICED design conferences. This has now metamorphisised into the Design Society which is the umbrella organisation for international design research activity.

Mogens boasts a disproportionately large percentage of successfully placed engineering designers graduating from his courses at DTU. His works on Domain Theory, Integrated Product Development, DfA and his contributions to the Theory of Technical Systems are considered amongst the seminal works of design theory. He is currently formalising his view and approaches to function and property reasoning which he considers to be key to engineering design thinking.

Ken Wallace was awarded his BSc in Mechanical Engineering in 1967 after which he worked in the design and development departments of Rolls-Royce's Aero-Engine Division until 1971.

In 1977 Ken was appointed Lecturer in Engineering Design at the University of Cambridge and spent the next 30 years working on design education and design research, with a special interest in systematic design methods. He is well known for translating and editing Pahl and Beitz's classic reference text Konstruktionslehre. The first English edition appeared in 1984 and two further editions were published in 1995 and 2007.

Ken was responsible for establishing the Cambridge Engineering Design Centre (EDC) in 1991 and was its first Director. In 1997 he stepped down as Director in order to set up of the University Technology Partnership (UTP), funded by Rolls-Royce and BAE SYSTEMS. A notable success of the UTP was a design method for capturing design rationale. This was embodied as the software tool DRed, which is now used throughout Rolls-Royce. In 2005 DRed won the Rolls-Royce Research and Technology Director's Award for Creativity.






TECHNICAL VISIT 1

Practical information

Price of 400 DKK includes return coach fare from Copenhagen Central Station, plus entrance tickets for Roskilde Cathedral and the Viking Ship Museum. In order for the excursion to be held, a minimum of 30 delegates will have to sign up. There is room for a maximum of 40 delegates. Payment can be made onsite at the ICED11 Conference only at the registration desk.

For any queries regarding the visit please contact guide Georg K. Christensen (gkch@man.dtu.dk).

In the case of cancellation, delegates will receive a full refund of this payment.

09:00	DEPARTURE FROM COPENHAGEN CENTRAL STATION (KBH H)	
09:30	RADIOMETER	
		<p>Presentation at Radiometer: "Design and Production" by R&amp;D director Tommy Bysted and leader of Lean activities Mads Friis.</p> <p>A guided tour at production facilities. Radiometer is a leading provider of advanced acute care testing solutions with an annual turnover of DKK 2.1 billion and is owned by US-based Danaher Corporation.</p>
11:30	ROSKILDE CATHEDRAL	
		<p>Tour of Roskilde Cathedral, the burial site of Danish Kings since 1400 AD.</p> <p>A UNESCO Site</p>
12:00	LUNCH IN ROSKILDE AT RESTAURANT "VIVALDI" AT TOWN SQUARE	
13:00	VIKING SHIP MUSEUM ROSKILDE	
		<p>The Viking Ship Museum in Roskilde is the Danish museum for ships, seafaring and boatbuilding culture in ancient and medieval times.</p> <p>The Viking Ship Hall, the oldest part of the museum, was opened in 1969. It was designed as a large showcase to display the five Viking ships found at Skuldelev. The hall also houses special temporary exhibitions and a cinema, where a film about the excavation of the ships is shown.</p> <p>Photo: Werner Karrasch; © Vikingeskibsmuseet i Roskilde</p>
15:00	DEPARTURE FOR COPENHAGEN CENTRAL STATION - EXPECTED ARRIVAL, 15:40	




TECHNICAL VISIT 2

Practical information

Price of 300 DKK includes bus fare bus fare to and from Copenhagen Central Station, lunch at Fritz Hansen and entrance ticket for Frederiksborg Castle. In order for excursion to be held a minimum of 40 delegates will have to sign up.

For queries regarding the visit please contact guide Hans Peter Lomholt Bruun (hplb@man.dtu.dk).

In the case of cancellation, delegates will receive a full refund of this payment.

09:00	DEPARTURE AT - COPENHAGEN CENTRAL STATION (KBH H)	
10:00	FRITZ HANSEN	
		<p>Presentation at Fritz Hansen in Vassingerød and their world renowned designer furniture. The trip includes a guided tour in their automated manufacturing plant.</p> <p>Fritz Hansen is in partnership with some of the world's most recognized architects including Arne Jacobsen, Poul Kjaerholm and Hans J. Wegner.</p>
12:30	LUNCH AT FRITZ HANSEN	
13:30	FOSS	
		<p>Presentation of FOSS in Hillerød and guided tour of production facilities. FOSS is the leading provider of dedicated analytical solutions to a broad range of industries. FOSS will present some of its new products, and give insight into the development process behind.</p>
15:45	FREDERIKSBORG CASTLE	
		<p>Tour round the castle and the gardens. Frederiksborg Castle is the largest Renaissance Castle in Scandinavia. It was built in the first decades of the 17th century by King Christian IV and incorporates the finest Renaissance architecture and craftsmanship.</p>
17:15	DEPARTURE FOR COPENHAGEN CENTRAL STATION - EXPECTED ARRIVAL, 18:00	



BANKS

Normal banking hours are from 10:00 to 16:00 Monday to Friday. On Thursday banking hours are extended to 18:00. Extended banking facilities are available at Copenhagen Central Railway Station, 7 days/week between 07:00 and 21:00. There are ATMs usually located in connection with a bank branch, which accept a variety of international credit cards. The cards accepted are indicated on the dispenser. DTU has no bank, but an ATM.

CLIMATE

The weather in Denmark in August is normally very pleasant, usually sunny. However, on occasion an umbrella may be useful. Daytime average temperature is around 20°C, evening temperature around 10°C. For more information please see [www.dmi.dk](http://www.dmi.dk).

CREDIT CARDS

Major credit and charge cards such as Visa, MasterCard, American Express, and Diners, are widely accepted at most establishments.

CURRENCY/CURRENCY EXCHANGE

The local currency is the Danish kroner. Foreign currencies can be exchanged either in banks or with a moneychanger conveniently located in the city.

ELECTRICITY

Electricity is supplied at 230 volts A/C, 50 Hz cycle. If you are travelling with electrical or electronic devices be sure to bring a two-pin continental adapter with you. On request, most hotels can provide transformers/adapters to guests.

EMERGENCY SERVICES

Police - Ambulance - Fire Brigade \* Dial 112

INTERNATIONAL CALLS AND MOBILE COMMUNICATION

The international country code for Denmark is 45. The outgoing code is 00 followed by the relevant country code (e.g. 0044 for the United Kingdom). There are no city codes and all local phone numbers are eight digits. There are several GSM mobile telephone networks, which have roaming agreements with most international mobile phone companies.

LIABILITY AND INSURANCE

Neither the Organisers (ICED) nor the Conference Secretariat DIS will assume any responsibility whatsoever for damage or injury to persons or property during the Conference. Participants are recommended to arrange for their personal travel and health insurance.

LOCAL TRANSPORTATION

The Metro train from Copenhagen Airport offers you a direct train every 4-6 minutes to the city centre of Copenhagen and will take approximately 14 minutes. Please check [www.m.dk](http://www.m.dk), [www.moviatrafik.dk](http://www.moviatrafik.dk), [www.rejseplanen.dk](http://www.rejseplanen.dk) or [www.copenhagenet.dk/CPH-Transport.htm](http://www.copenhagenet.dk/CPH-Transport.htm) for further information. The regular (regional) train departs from the airport every 15 minutes for the main central station (København H). A taxi from Copenhagen Airport to the city centre is approximately DKK 250 (no extra charges for suitcases).

PROGRAMME CHANGES

The Organisers reserve the right to adjust or change the programme as necessary.

SHOPS

The Shops are open from 10:00 to 18:00 Monday through Thursday, 10:00 to 19:00 on Friday and 09:00 to 17:00 on Saturday/Sunday.

SIGHTSEEING

For further information about Copenhagen, please check [www.visitcopenhagen.com](http://www.visitcopenhagen.com) or visit the Copenhagen Visitor Centre - Vesterbrogade 4A - 1620 København V. - Tlf.: 7022 2442 - E-mail: [touristinfo@woco.dk](mailto:touristinfo@woco.dk)

TIMEZONE

Denmark is set to Central European Time (CET) which is GMT +2 (summer), GMT +1 (winter).

TIPS

Tips are always included in the prices given in taxis and restaurants.

WATER

Water from the tap is safe to drink in Copenhagen. Bottled and mineral water are also readily available in supermarkets or convenience stores.

WIRELESS INTERNET

On check-in you will be provided with a username and password giving you access to the wireless network at the conference venue.

Alternately you can connect via eduroam, as DTU is an eduroam location. We strongly advise you to check with your university's IT service, about whether your university supports eduroam, before arriving at DTU – this would make life much easier for you. Read about eduroam on <http://www.eduroam.org/>

ICED11 FOOD AND DRINKS

We recommend that the ICED11 delegates head to Gråbrødretorv (see position on map p179) after conference hours to take advantage of our associated restaurants and their offers (show your ICED11 name badges to obtain the offers).

**Café G.**  
Contemporary International cuisine  
ICED11 offer: 15% off final bill (only if food is ordered).

**Wining & Dining**  
3 course set menu includes 2 chosen white and red wines. Classic French cuisine.  
ICED11 offer: A complementary glass of champagne.

**Ristorante Uno**  
A rough gem with a wide-ranging menu of Italian cuisine.  
ICED11 offer: 25% off your final bill. (30% at lunch).

**Ristorante Sole d'Italia**  
Italian restaurant with a good selection of wines and beers.  
ICED11 offer: 25% off your final bill. (30% at lunch).

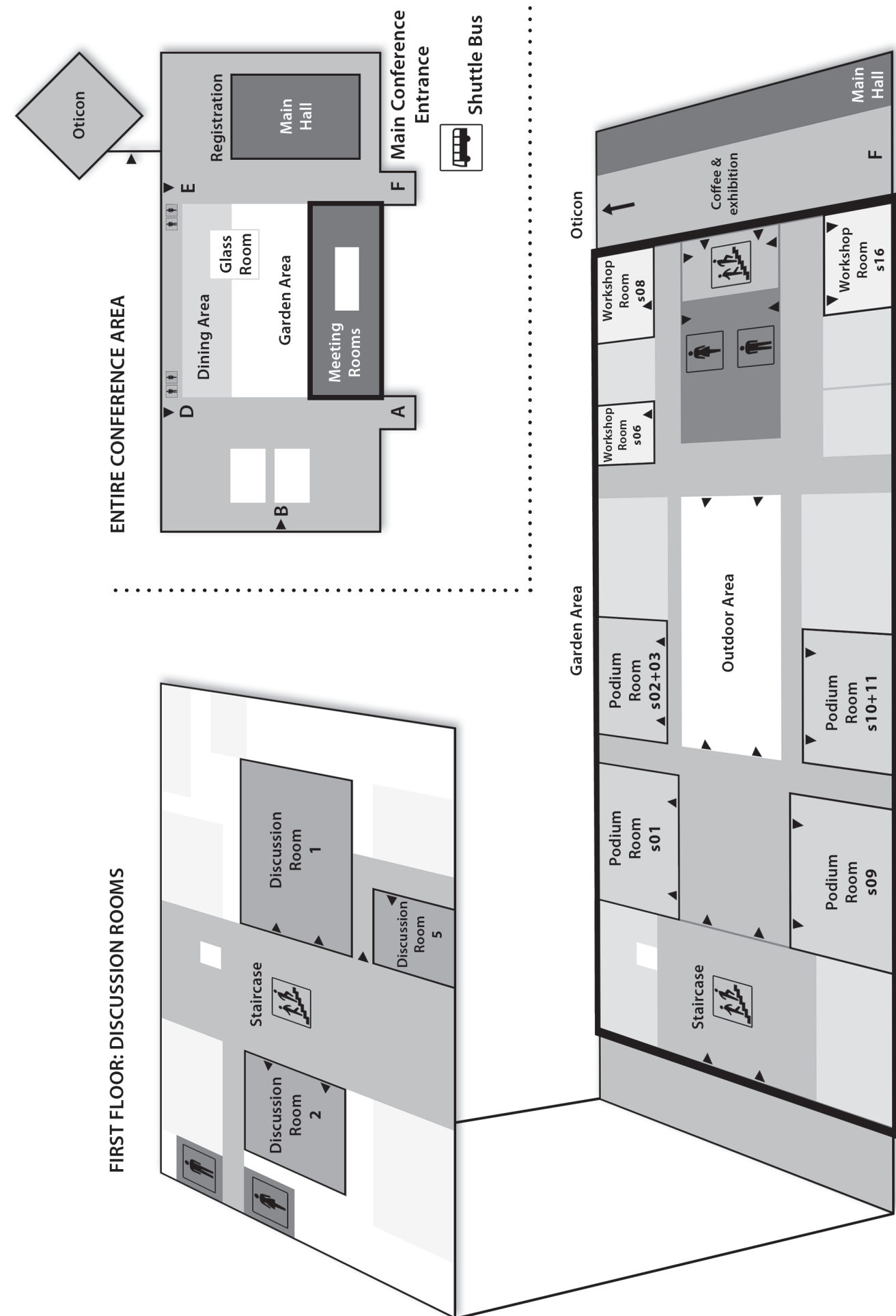
**LePavé**  
Romantic and relaxing, serving French cuisine with ample portions.  
ICED11 offer: A complementary glass of champagne.

**Sporvejen**  
"Probably the best burger in town"  
ICED11 offer: 10% off final bill.

Gråbrødretorv  
Historically a Franciscan monastery founded in the 1238th

Skindergade

# THE CONFERENCE SUITE



# TRAVEL LOGISTICS



